RULES AND REGULATIONS FOR THE CLASSIFICATION OF INLAND WATERWAYS SHIPS

REGULATIONS

NOVEMBER 2008

PART 1

Lloyd's Register

A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Inland Waterways Ships

Introduction

The Rules are published as a complete set, individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
(b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
(c) In another Part, e.g. *see* Pt 2, Ch 1,3 (i.e. down to Section).

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig 2.3.5 (i.e. Chapter, Section and Figure Number).
(b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
(c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

Rules updating

The Rules are published periodically and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda.

November 2008

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Part 1

Section 1

1.1 Lloyd's Register (hereinafter referred to as 'LR'), which is recognized under the laws of the United Kingdom as a corporate body and a charity established for the benefit of the community, was founded in 1760. It was established for the purpose of producing a faithful and accurate Classification of Merchant Shipping. It now primarily produces Classification Rules.

1.2 Classification services are delivered to clients by a number of other members of the Lloyd's Register Group, including: Lloyd's Register EMEA, Lloyd's Register Asia, Lloyd's Register North America, Inc., and Lloyd's Register Central and South America Limited.

1.3 The Lloyd's Register Group (hereinafter referred to as 'the LR Group') comprises charities, other forms of organisation and non-charitable companies, with the latter supporting the charities in their main goal of enhancing the safety of life and property, at sea, on land and in the air, for the benefit of the public and the environment.

Section 2

2.1 LR remains the sole classification society in the LR Group. LR is managed by a Board of Trustees (hereinafter referred to as 'the Board').

The Board has:

Appointed a Classification Committee and determined its powers and functions;
Appointed Technical Committees and determined their powers, functions and duties.

2.2 The LR Group has established National and Area Committees in the following:

Countries:
Australia (via Lloyd's Register Asia)
Canada (via Lloyd's Register North America, Inc.)
China (via Lloyd's Register Asia)
Egypt (via Lloyd's Register EMEA)
Federal Republic of Germany
(via Lloyd's Register EMEA)
France (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)
Japan (via Lloyd's Register)
New Zealand (via Lloyd's Register Asia)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

Areas:
Benelux (via Lloyd's Register EMEA)
Central America (via Lloyd's Register Central and South America Ltd)
Nordic Countries (via Lloyd's Register EMEA)
South Asia (via Lloyd's Register Asia)
Asian Shipowners (via Lloyd's Register Asia)
Greece (via Lloyd's Register EMEA)

Section 3

3.1 LR's Technical Committee is at present composed of:

	Total
Ex officio members:	
• The Chairman of LR	1
• The Chairman of the Classification Committee	1
Members Nominated by:	
• The Board	18
• The Royal Institution of Naval Architects	2
• The Institution of Engineers and Shipbuilders in Scotland	2
• The Institute of Marine, Science and Technology	2
• The Institution of Mechanical Engineers	2
• The Shipbuilders' and Shiprepairers' Association	2
• The Short Sea Group of the Chamber of Shipping	1
• The Society of Consulting Marine Engineers and Ship Surveyors	1
• The Institute of Materials	1
• The UK Steel Association	1
• The Honourable Company of Master Mariners	2
• The Institution of Electrical Engineers	1
• Federation of British Electrotechnical and Allied Manufacturers' Associations	1
• The Technical Committee	18
• The Technical Committee (from other countries)	18
• The Institute of Refrigeration	1
• International Oil Companies	2
• Association of European Shipbuilders and Shiprepairers	1
• Greek Shipping Co-operation Committee	1
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3.2 In addition to the foregoing:

(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committee.

(b) A maximum of five representatives from National Administrations may, with the consent of the Technical Committee, be co-opted to serve on the Technical Committee. Such representatives may also be elected as members of the Technical Committee under one of the categories identified in 3.1.

(c) Further persons may, with the consent of the Technical Committee, be co-opted to serve on the Technical Committee.

3.3 All elections are subject to confirmation by the Board.

3.4 The function of the Technical Committee is to consider any technical problems connected with LR's business and with the exception of changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies, any proposed alterations in the existing Rules and to frame new Rules for classification as deemed necessary.

3.5 The term of office of the Chairman and of all members of the Technical Committee is five years. Members may serve one additional term of office with the approval of the Board. The term of the Chairman may be extended with the approval of the Board.

3.6 In the case of continuous non-attendance of a member, the Technical Committee may withdraw his/her membership.

3.7 Meetings of the Technical Committee are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year.

3.8 Any proposal involving any alteration in, or addition to, Part 1, Chapter 1 of Rules for Classification is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification will, following approval by the Technical Committee, be submitted to the Board for adoption.

3.9 The Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and

(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organization or industry or private individuals for the purpose of considering any particular problem.

■ *Section 4*

4.1 LR's Naval Ship Technical Committee (hereinafter referred to as 'the NSTC') is at present composed of up to 50 members and includes nominees of:

- The Royal Navy and the UK Ministry of Defence;
- The Defence Evaluation and Research Agency;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;
- Various maritime bodies and institutions, nominated by the NSTC;
- The Chairman of LR and Chairman of the Classification Committee who are *ex officio* members.

4.2 All elections are subject to confirmation by the Board.

4.3 All members of the NSTC are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

4.4 The term of office of the NSTC Chairman and of all members of the NSTC is five years. Members may serve one additional term of office with the approval of the Board. The term of the Chairman may be extended with the approval of the Board.

4.5 In the case of continuous non-attendance of a member, the NSTC may withdraw that person's membership.

4.6 The function of the NSTC is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules.

4.7 Meetings of the NSTC are convened as necessary but there will be at least one meeting per year.

4.8 Following approval by the NSTC, details of new Rules (or amendments) will be submitted to the Board for adoption.

■ *Section 5*

5.1 LR has the power to adopt, and publish as deemed necessary, Rules relating to Classification and has (in relation thereto) provided the following:

(a) Except in the case of a special directive by the Board, no new Regulation or alteration to any existing Regulation relating to classification or to class notations is to be applied to existing ships.

(b) Except in the case of a special directive by the Board, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and shipowner for construction of the ship has been signed, nor within six months of its adoption. The date of 'contract for construction' of a ship is the date on which the contract to build the ship is signed between the prospective shipowner and the ship builder. This date and the construction number (i.e. hull numbers) of all the vessels included in the contract are to be declared by the party applying for the assignment of class to a newbuilding. The date of 'contract for construction' of a series of sister ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective shipowner and the ship builder. In this section a 'series of sister ships' is a series of ships built to the same approved plans for classification purposes, under a single contract for construction. The optional ships will be considered part of the same series of sister ships if the option is exercised not later than 1 year after the contract to build the series was signed. If a contract for construction is later amended to include additional ships or additional options, the date of 'contract for construction' for such ships is the date on which the amendment to the contract is signed between the prospective shipowner and the ship builder. The amendment to the contract is to be considered as a 'new contract'. If a contract for construction is amended to change the ship type, the date of 'contract for construction' of this modified vessel, or vessels, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to LR. Sister ships may have minor design alterations provided that such alterations do not affect matters related to classification.

(c) All reports of survey are to be made by Surveyors authorised by members of the LR Group to survey and report (hereinafter referred to as 'the Surveyors') according to the form prescribed, and submitted for the consideration of the Classification Committee.

(d) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorized in writing by that owner, to any other person or organization.

(e) Notwithstanding the general duty of confidentiality owed by LR to its client in accordance with the LR Rules, LR clients hereby accept that, LR will participate in the IACS Early Warning System which requires each IACS member to provide its fellow IACS members and Associates with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and utilised to facilitate the proper working of the IACS Early Warning System LR will provide its client with written details of such information upon sending the same to IACS Members and Associates.

(f) Information relating to the status of classification and statutory surveys and suspensions/withdrawals of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(g) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Classification Committee that the Classification Committee assigns to it.

■ *Section 6*

6.1 No LR Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

■ *Section 7*

7.1 LR has power to withhold or, if already granted, to suspend or withdraw any class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee to any member of the LR Group.

■ *Section 8*

8.1 When providing services LR does not assess compliance with any standard other than the applicable LR Rules, international conventions, and other standards agreed in writing.

8.2 In providing services, information or advice, the LR Group does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of any of the LR Group or caused by any inaccuracy in any information or advice given in any way by or on behalf of the LR Group even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR's services or relies on any information or advice given by or on behalf of the LR Group and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of the LR Group or any negligent inaccuracy in information or advice given by or on behalf of the LR Group, then a member of the LR Group will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

8.3 Notwithstanding the previous clause, the LR Group will not be liable for any loss of profit, loss of contract, loss of use or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of the LR Group even if held to amount to a breach of warranty.

8.4 Any dispute about LR's services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

Section

■ *Section 1* Conditions for classification

1.1 General

1.1.1 These Rules and Regulations are framed for Inland Waterways Ships operating in Zone 3. Proposed scantlings and arrangements for ships intended to operate in Zones 2 or 1, will be specially considered. *See also* 2.1.1 to 2.1.3 for Zone definitions.

1.1.2 Ships referred to in this Chapter are defined in Parts 3 and 4 of these Rules.

Machinery referred to in this Chapter is defined in Parts 5 and 6 of these Rules.

1.1.3 Ships built in accordance with Lloyd's Register's (hereinafter referred to as LR) Rules and Regulations, or in accordance with requirements equivalent thereto, will be assigned a class in the *Register Book* and will continue to be classed as long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules. Classification will be conditional upon compliance with LR's requirements for both hull and machinery.

1.1.4 The Committee, in addition to requiring compliance with LR's Rules, may require to be satisfied that ships of special types are suitable for the conditions of the service contemplated.

1.1.5 Any damage, defect or breakdown, which could invalidate the conditions for which a class has been assigned, is to be reported to LR without delay.

1.1.6 The Rules are framed on the understanding that ships will be properly loaded and handled. They do not, unless stated or implied in the class notation, provide for special distributions or concentrations of loading. The Committee may require additional strengthening to be fitted in any ship, which, in their opinion, would otherwise be subjected to severe stresses due to particular features in the design, or where it is desired to make provision for exceptional loaded or ballast conditions. In such cases, particulars are to be submitted for consideration, *see also* the relevant ship type Chapters in Part 4.

1.1.7 The Rules are framed on the understanding that ships will not be operated in environmental conditions more severe than those agreed for the design basis and approval, without the prior agreement of LR.

1.1.8 For ships, the arrangements and equipment of which are required to comply with the requirements of either the:

- European Agreement concerning the international carriage of dangerous goods by inland waterways (ADN); or
- European Agreement concerning the international carriage of dangerous goods by inland waterways on the river Rhine (ADNR); or
- Règlement de visite des bateaux du Rhin 1995 (Rhine inspection regulations) or
- EC Directive (2006/87/EC) DIRECTIVE of the EUROPEAN PARLIAMENT and of the COUNCIL of 12 December 2006 laying down technical requirements for inland waterway vessels; or
- Any National regulations specified by the Government of the Flag State,

and applicable Amendments thereto, the Committee requires the applicable Certificates to be issued by a National Administration, or by LR, or by an IACS Member when so authorized.

1.2 Advisory services

1.2.1 The Rules do not cover certain technical characteristics, such as stability, trim, hull vibration, etc., but the Committee is willing to advise on such matters although it cannot assume responsibility for them.

1.2.2 Where a vessel is so badly damaged that class has to be suspended, LR is prepared to assist the Owner with advice if requested.

■ *Section 2* Character of classification and class notations

2.1 Definitions

NOTE
For the purpose of class notations, the definitions given in 2.1.1 to 2.1.13 will apply.

2.1.1 **Zone 1.** A zone where the maximum significant wave height based on long-term significant wave height statistics, excluding the highest five per cent of the observed waves, does not exceed 1,6 m.

2.1.2 **Zone 2.** A zone where the maximum significant wave height based on long-term significant wave height statistics, excluding the highest five per cent of the observed waves, does not exceed 1,0 m.

2.1.3 **Zone 3.** A zone where the maximum significant wave height based on long-term significant wave height statistics, excluding the highest five per cent of the observed waves, does not exceed 0,5 m.

2.1.4 **Type notation.** One of the following Notations will be assigned to ships indicating that the ship has been arranged and constructed in compliance with the Rules and as defined in the relevant Chapter of Part 4. Details regarding further extensions of Class Notations as applicable for specific ship types are given in these Chapters as well.

- **'A1 I.W.W. Cargo Ship'** or **'A1 I.W.W. Cargo Barge'**. *See* Pt 4, Ch 1
- **'A1 I.W.W. Container Ship'** or **'A1 I.W.W. Container Barge'**. *See* Pt 4, Ch 1
- **'A1 I.W.W. Bulk Carrier'** or **'A1 I.W.W. Bulk Carrier Barge'**. *See* Pt 4, Ch 1
- **'A1 I.W.W. Ferry'**, **'A1 I.W.W. Roll on-Roll off Ship'** or **'A1 I.W.W. Roll on-Roll off Barge'**. *See* Pt 4, Ch 2
- **'A1 I.W.W. Pontoon'** or **'A1 I.W.W. Pontoon, self propelled'**. *See* Pt 4, Ch 3
- **'A1 I.W.W. Tanker Type G'** or **'A1 I.W.W. Barge Type G'**. *See* Pt 4, Ch 5
- **'A1 I.W.W. Tanker Type C'** or **'A1 I.W.W. Barge Type C'**. *See* Pt 4, Ch 6
- **'A1 I.W.W. Tanker Type N Closed'** or **'A1 I.W.W. Barge Type N Closed'**. *See* Pt 4, Ch 6
- **'A1 I.W.W. Tanker Type N Closed, Double Hull'** or **'A1 I.W.W. Barge Type N Closed, Double Hull'**. *See* Pt 4, Ch 6
- **'A1 I.W.W. Tanker Type N Open with flame screens'** or **'A1 I.W.W. Barge Type N Open with flame screens'**. *See* Pt 4, Ch 6
- **'A1 I.W.W. Tanker Type N Open with flame screens, Double Hull'** or **'A1 I.W.W. Barge Type N Open with flame screens, Double Hull'**. *See* Pt 4, Ch 6
- **'A1 I.W.W. Tanker Type N Open'** or **'A1 I.W.W. Barge Type N Open'**. *See* Pt 4, Ch 6
- **'A1 I.W.W. Tanker Type N Open, Double Hull'** or **'A1 I.W.W. Barge Type N Open, Double Hull'**. *See* Pt 4, Ch 6
- **'A1 I.W.W. – Water tanker'** or **'A1 I.W.W. – Wine tanker'** or **'A1 I.W.W. – Edible oil tanker'** or **'A1 I.W.W. – Water barge'** or **'A1 I.W.W. – Wine barge'** or **'A1 I.W.W. – Edible oil barge'**. *See* Pt 4, Ch 7
- **'A1 I.W.W. Pusher Tug'** or **'A1 I.W.W. Launch'**. *See* Pt 4, Ch 8
- **'A1 I.W.W. Passenger Ship'**. *See* Pt 4, Ch 9.

2.1.5 **Cargo notation.** A notation indicating that the ship has been designed, modified or arranged to carry one or more particular cargoes, e.g. sulphuric acid. Ships with one or more particular cargo notations are not thereby prevented from carrying other cargoes for which they are suitable.

2.1.6 **Loading sequence notation (L.S.).** A notation indicating that the ship has been designed, modified or arranged to be loaded and/or discharged according to a special or to a defined sequence, e.g. loading sequence 'O', loading sequence 'D', *see* Pt 3, Ch 4,2 and relevant ship type Chapters in Part 4.

2.1.7 **Loading notation.** A notation indicating that the ship has been designed, modified or arranged for unusual and/or non-uniform cargo distributions, e.g. 'specified non-uniform loading conditions', *see* Pt 3, Ch 4,2 and relevant ship type Chapters in Part 4.

2.1.8 **Ice notation (ICE).** A notation indicating that the ship has been designed, modified or arranged to navigate in ice.

2.1.9 **Zone notation.** A notation indicating that the ship has been designed, modified or arranged to operate in Zones 1 and/or 2, where conditions as specified for the particular zone are not being exceeded during any voyage of the ship.

2.1.10 **Dangerous Goods notation**. Double-hull dry cargo ships built in compliance with Chapter 9, Section 9.1.0.80 of the ADN or ADNR and complying with the additional requirements of Pt 4, Ch 1, 12 will be eligible to be classed:

'DG'.

2.1.11 **Pressure valve setting notation**. Tankers complying with the requirements of Pt 4, Ch 5, 6 or 7 will, in case of tanks of the closed type, have their design pressure valve setting of the relief valves of the cargo tanks entered in the class notation, e.g.:

'p.v. +50 kPa'.

2.1.12 **Specific gravity notation**. Tankers complying with the requirements of Pt 4, Ch 5, 6 or 7 will have the design specific gravity of the cargo tanks entered in the class notation, e.g.:

'S.G. 1.20'.

2.1.13 **Corrosion resistant materials**. Tankers complying with the requirements of Pt 4, Ch 5, 6 or 7 where the cargo tanks have been constructed of corrosion resistant materials, e.g. stainless steel or have been lined with corrosion resistant linings, e.g. rubber lining will have the following notations entered in the class notation:

'CR (s.stl)', 'CR (r.l)'.

2.2 Character symbols

2.2.1 All Inland Waterways Ships, when classed, will be assigned one or more character symbols as applicable. For the majority of ships, the character assigned will be **'✠A1 I.W.W.'** or **'A1 I.W.W'**.

2.2.2 A full list of character symbols for which ships may be eligible is as follows:

✠ This distinguishing mark will be assigned, at the time of classing, to new ships constructed under LR's Special Survey, in compliance with the Rules, and to the satisfaction of the Committee.

A This character letter will be assigned to all ships which have been built or accepted into class in accordance with LR's Rules and Regulations, and which are maintained in good and efficient condition.

1 This character figure will be assigned to:

(a) Ships having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with the Rules.

(b) Ships classed for a special service, for which no specific anchoring and mooring Rules have been published, having on board, in good and efficient condition, anchoring and/or mooring equipment approved by the Committee as suitable and sufficient for the particular service.

(c) Ships having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with established National or International Regulations and approved by the Committee as suitable and sufficient for the particular service. The service limits where applicable may be entered in the class notation.

N This character letter will be assigned to ships on which the Committee has agreed that anchoring and mooring equipment need not be fitted in view of their particular service.

T This character letter will be assigned to ships which are intended to perform their primary designed service function only while they are anchored, moored, towed or pushed, and which have, in good and efficient condition, adequately attached anchoring, mooring, towing or pushing equipment which has been approved by the Committee as suitable and sufficient for the intended service.

2.2.3 In cases where the equipment is found to be seriously deficient in quality or quantity, the class of the ship will be liable to be withheld.

2.3 Class notations (hull)

2.3.1 When considered necessary by the Committee, or when requested by an Owner and agreed by the Committee, a class notation will be appended to the character of classification assigned to the ship. This class notation will consist of one of, or a combination of: a type notation, a cargo notation, a loading sequence notation, a loading notation, an 'ICE' notation and zone notation, e.g. **A1 I.W.W., L.S. 'O', ICE**, Zone 2.

2.3.2 Details of additional requirements in view of a ship type, particular cargoes, loading sequence, Ice or Zones 1 and 2, are given in the Chapters of Parts 3 and 4 which apply to such ships and cargoes.

2.3.3 Service extension notations (service in areas which are not considered as Inland Waterways) may be assigned where, under specified conditions. These conditions are such that the structural and system requirements specified in these Rules are sufficient.

These conditions are to be included in the class notation (e.g. geographical limits, maximum permissible distance out to sea, windforce, sea-condition, as appropriate).

Where operation of the ship in the extended service area is permitted in association with defined loading conditions only, this service restriction is also to be included in the class notation.

These notations may be assigned in one of the following forms:

(a) **Specified route service.** Service between two or more ports or other geographical features, which will be indicated in the *Register Book*, e.g. 'Service between Flushing and Ostend, maximum five miles seaward and windforce not exceeding Beaufort scale 5 from sea or Beaufort scale 6 from land and in association with defined loading conditions'.

(b) **Specified operating area service.** Service within one or more geographical area(s), which will be indicated in the *Register Book*, e.g. 'Baltic Sea Service' (within specified geographical limits and under specified conditions).

2.4 Class notations (machinery)

2.4.1 The following class notations may be assigned as considered appropriate by the Committee:

IGS This notation will be assigned when a tanker, complying with the requirements of Part 4, Chapters 5, 6 or 7, is fitted with approved arrangements for inerting the cargo tanks.

✠ LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations, *see also* Pt 5, Ch 1,7.1.

$\overline{✠}$ LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed under the survey of a recognized authority in accordance with Rules and Regulations equivalent to those of LR and has been installed and tested under LR's Special Survey in accordance with LR's Rules and Regulations.

[✠] LMC This notation will be assigned when the propelling arrangements, steering systems, pressure vessels and the electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules and Regulations. Other items of machinery for propulsion and electrical power generation including propulsion gearing arrangements and other auxiliary machinery for essential services that are in compliance with LR Rules and supplied with the manufacturer's certificate will be acceptable under this notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See* 2.6.2.

Classification Regulations

LMC This notation (without ✠) will be assigned when the propelling and essential auxiliary machinery has neither been constructed nor installed under LR's Special Survey but the existing machinery, its installation and arrangement, has been tested and found to be acceptable to LR. This notation is assigned to existing ships in service accepted or transferring into LR class.

MCH This notation will be assigned when the propelling and essential auxiliary machinery has been installed and tested under LR's survey requirements and found to be acceptable to LR. Items of machinery and equipment for propelling and auxiliary machinery for essential services supplied with the manufacturer's certificate will be acceptable under this class notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See* 2.6.3.

2.4.2 Machinery class notations will not be assigned to ships the hulls of which are not classed or intended to be classed with LR.

2.4.3 The notations ✠**LMC**, ✠̄ **LMC**, **[✠]LMC**, **LMC** (without ✠) and **MCH** will in general not be assigned to non-propelled craft, but individual cases will be considered on their merits.

2.5 Descriptive notes

2.5.1 In addition to any class notations, an appropriate descriptive note may be entered in Column 6 of the *Register Book* indicating the type of ship in greater detail than is contained in the class notation, and/or providing additional information about the ship's design and construction. This descriptive note is not an LR classification notation and is provided solely for the information of users of the *Register Book.*

2.6 Application notes

2.6.1 **Propelling and essential auxiliary machinery** includes machinery, equipment and systems installed for the ship to be under inland waterway navigation conditions and that are necessary for the following:

(a) Maintaining the watertight and weathertight integrity of the hull and spaces within the hull.
(b) The safety of the ship, machinery and personnel on board.
(c) The functioning and dependability of propulsion, steering and electrical systems.
(d) The operation and functioning of control engineering systems for the monitoring and safety of propulsion and steering systems.
(e) The operation and functioning of emergency machinery and equipment.

2.6.2 **Manufacturer's certificate** for assignment of the **[✠]LMC** notation. Acceptance of the manufacturer's certificate for items of machinery for propulsion (including propulsion gearing with single input/output arrangements) and for electrical power generation and for other auxiliary machinery for essential services is subject to the following:

(a) The ship is a cargo ship or a tanker that is required to comply with specific Regulatory Body for Inland Maritime Transport requirements for construction under survey relating to the carriage of particular types of hazardous cargoes such as oils, chemicals and dangerous goods.
(b) The class notation is acceptable to the relevant Administration.
(c) Propulsion power is provided by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(d) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(e) The design and manufacture standards for all machinery and associated systems are the applicable LR Rules.
(f) The machinery and equipment is manufactured under a recognised quality control system.
(g) Propellers, propulsion shafting and multiple input/output gearboxes are not included within the scope of propulsion arrangements for acceptance of a manufacturer's certificate.

2.6.3 **Manufacturer's certificate** for assignment of the **MCH** notation. Acceptance of the manufacturer's certificate for propelling and essential auxiliary machinery is subject to the following:

(a) The ship is a cargo ship or a tanker that is not required to comply with specific Regulatory Body for Inland Maritime Transport requirements for construction under survey relating to the carriage of particular types of hazardous cargoes such as oils, chemicals and dangerous goods.
(b) Propulsion power is provided by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(c) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(d) The power of any engine or gas turbine is less than 2,250 kW and the cylinder bore of any diesel engine is not greater than 300 mm.
(e) The design and manufacturing standards for machinery and associated systems are the applicable LR Rules or other marine standards acceptable to LR.
(f) The machinery and equipment is manufactured under a recognised quality control system.

Section 3 Surveys – General

3.1 Statutory surveys

3.1.1 The Committee will act, when authorized on behalf of Governments, in respect of National and International statutory safety and other requirements for passenger, cargo and other ship types.

3.2 New construction surveys

3.2.1 When it is intended to build a ship for classification with LR, constructional plans and all necessary particulars relevant to the hull, equipment and machinery as detailed in the Rules, are to be submitted for the approval of the Committee before the work is commenced. Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted for approval.

3.2.2 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of the Committee, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

3.2.3 The materials used in the construction of hulls and machinery intended for classification are to be of good quality and free from defects and are to be tested in accordance with the requirements of LR's *Rules for the Manufacture, Testing and Certification of Materials*. The steel is to be manufactured by an approved process at works recognized by the Committee. Alternatively, tests to the satisfaction of the Committee, will be required to demonstrate the suitability of the steel.

3.2.4 New ships intended for classification are to be built under LR's Special Survey. From the commencement of the work until the completion of the ship, the Surveyors are to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the Rules. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

3.2.5 Copies of approved plans (showing the ship as built), essential certificates and records, required loading and other instruction manuals are to be readily available for use when required by LR's Surveyors, and may be required to be kept on board.

3.2.6 When the machinery is constructed under LR's Special Survey, this survey is to relate to the period from the commencement of the work until the final test under working conditions. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

3.2.7 When arrangements are such that essential machinery can be operated by remote and/or automatic control equipment, the control equipment is to be arranged, installed and tested in accordance with LR's Rules and Regulations.

3.2.8 The date of completion of the Special Survey during construction of ships built under LR's inspection will normally be taken as the date of build to be entered in the *Register Book*. If the period between launching and commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated in the *Register Book*.

3.2.9 When a ship, upon completion, is not immediately commissioned but is laid-up for a period, the Committee, upon application by the Owner, prior to the ship proceeding to sea, will direct an examination to be made by LR's Surveyors which may include a survey in dry-dock. If, as the result of such a survey, the hull and machinery be reported in all respects free from deterioration, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

3.3 Existing ships

3.3.1 **Classification of ships not built under survey.** The requirements of the Committee for the classification of ships which have not been built under LR's Survey are indicated in Chapter 3. Special consideration will be given to ships transferring class to LR from another recognized Classification Society.

3.3.2 **Reclassification**. When reclassification or class reinstatement is desired for a ship for which the class previously assigned by LR has been withdrawn or suspended, the Committee will direct that a survey appropriate to the age of the ship and to the circumstances of the case, be carried out by LR's Surveyors. If, at such survey, the ship be found or placed in a good and efficient condition in accordance with the requirements of the Rules and Regulations, the Committee will be prepared to consider reinstatement of the original class or the assignment of such other class as may be deemed necessary.

3.3.3 The Committee reserves the right to decline an application for classification or reclassification where the prior history or condition of the ship indicates this to be appropriate.

3.4 Repairs and alterations

3.4.1 All repairs to hull, equipment and machinery which may be required in order that a ship may retain her class, *see* 1.1.5, are to be carried out to the satisfaction of LR's Surveyors. When repairs are effected at a port, terminal or location where the services of a Surveyor to LR are not available, the repairs are to be surveyed by one of LR's Surveyors at the earliest opportunity thereafter.

3.4.2 When at any survey the Surveyors consider repairs to be necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to the Committee by the Surveyors.

3.4.3 When, at any survey, it is found that any damage, defect or breakdown (*see* 1.1.5) is of a nature that does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable condition of class is to be imposed by the Surveyors and recommended to the Committee for consideration.

3.4.4 If a ship which is classed with LR is to leave harbour limits or protected waters under tow, the Owner is to advise LR of the circumstances prior to her departure.

3.4.5 If a ship which is classed with LR is taken in tow whilst at sea, the Owner is to advise LR of the circumstances at the first practicable opportunity.

3.4.6 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull, equipment, or machinery are to be submitted for approval, and such alterations are to be carried out to the satisfaction of LR's Surveyors.

3.5 Existing ships – Periodical Surveys

3.5.1 All classed ships having a service extension notation and regularly operating in sea areas for which a National or International Load Line Certificate is issued, are to be subjected to Annual Surveys. These surveys become due at yearly intervals, the first survey one year from the date of build or from the date of the Special Survey for classification, and should be held concurrently with the periodical load line inspection. The survey may be commenced within the period of three months before the due date and is to be completed not later than three months after the due date. The date of the last Annual Survey will be recorded on the ClassDirect Live website.

3.5.2 All classed passenger ships are to be subjected to Annual Surveys. These surveys become due at yearly intervals, the first survey one year from the date of build or from the date of the Special Survey for classification. The survey may be commenced within the period of three months before the due date and is to be completed not later than three months after the due date. The date of the last Annual Survey will be recorded on the ClassDirect Live website.

3.5.3 All classed ships, other than as mentioned in 3.5.1 and 3.5.2, are to be subjected to Intermediate Surveys. These surveys become due 30 months after the date of build or of the previous Special Survey and are to be completed within 6 months before and after the Intermediate Survey due date. The date of the last Annual Survey will be recorded on the ClassDirect Live website.

3.5.4 All classed ships, are to be subjected to Special Surveys. These surveys become due at five yearly intervals, the first one five years from the date of build or date of Special Survey for classification, and thereafter five years from the date of the previous Special Survey. The date of the last Annual Survey will be recorded on the ClassDirect Live website.

3.5.5 Attention is to be given to any relevant Statutory Requirements of the National Authority of the country in which the ship is registered and/or of International Conventions if the ship is also intended to make international voyages.

3.5.6 It is the responsibility of Owners to ensure that all surveys for the maintenance of class are carried out at the proper time and in accordance with the Regulations.

3.5.7 The Owners should also notify LR whenever a ship can be examined in dry-dock or on a slipway on account of damage or defects between Periodical Surveys.

3.5.8 When it is inconvenient for an Owner to fulfil all the requirements of a Special Survey at its due date, the Committee will be prepared to consider its postponement, either wholly or in part, provided that LR's Surveyors are afforded an opportunity, about the due date, of assessing the general condition of the hull. For this purpose, the Committee will normally call for a General Examination of the ship of sufficient extent and which may include dry-docking (depending on age and records of the ship) to be assured that its condition is satisfactory for the period of grace desired, which is not to exceed 12 months from the due date. Attention is drawn to relevant regulations of the National Authorities of the country where the ship is registered.

3.5.9 Machinery is to be submitted to the surveys detailed in Ch 3,10 to Ch 3,16.

3.5.10 Complete Surveys of machinery become due at five yearly intervals, the first one five years from the date of build or date of first classification as recorded in the *Register Book*, and thereafter five years from the date of the previous Complete Survey.

3.5.11 If it is found desirable that any part of the machinery should be examined again before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

3.5.12 Boiler Surveys, examination of steam pipes and Screwshaft Surveys are to be carried out as stated in Ch 3,13 to Ch 3,15. The date of the last Annual Survey will be recorded on the ClassDirect Live website.

3.5.13 Where an inert gas system is fitted on board a ship, the system is to be surveyed at $2^1/_2$-yearly intervals or at the Intermediate Survey and at the Special Survey. Survey requirements are given in Ch 3,16.

3.5.14 When it is inconvenient for an Owner to fulfil all the requirements of a Complete Survey at its due date, the Committee will be prepared to consider its postponement, either wholly or in part, provided that LR's Surveyors are afforded an opportunity, about the due date, of assessing the general condition of the machinery. For this purpose, the Committee will normally require a General Examination to be made of sufficient extent to assure them that the condition of the machinery is satisfactory for the period of grace desired, which is not to exceed 12 months from the due date. Attention is drawn to relevant Regulations of the National Authorities of the country where the ship is registered.

3.5.15 Where the ship is fitted with a classed dynamic positioning equipment, the system is to be examined at each Intermediate Survey and at the due time of the Special Survey in accordance with the requirements of Ch 3,10.2.4. (Intermediate) and Ch 3,10.3.13 (Special Survey).

3.6 Certificates

3.6.1 When the required reports, on completion of the Special Survey of new or existing ships which have been submitted for classification, have been received from the Surveyors and approved by the Committee, a certificate of First Entry of Classification, signed by the Chairman, or the Deputy Chairman and Chairman of the Sub-Committees of Classification, will be issued to Builders or Owners.

3.6.2 A certificate of class valid for five years subject to Annual and/or Intermediate Surveys will also be issued to the Owners

3.6.3 LR's Surveyors are permitted to issue provisional (interim) certificates to enable a ship intended for classification, or already classed, with LR to commence service or to proceed on its voyage (or to continue service in the case of a fixed or tethered ship) provided that in their opinion it is in a fit and efficient condition. Such certificates will embody the Surveyor's recommendations for classification or for continuance of class, but in all cases are subject to confirmation by the Committee.

3.6.4 The full class notation and abbreviated descriptive notes shall be stated on the Certificate of Class and provisional (interim) certificate.

3.7 Notice of surveys

3.7.1 It is the responsibility of the Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time and in accordance with the instructions of the Committee. Information is available to Owners on the ClassDirect Live website.

3.7.2 LR will give timely notice to an Owner about forthcoming surveys by means of a letter or a computer printout of a ship's Quarterly Listing of Surveys, Conditions of Class and Memoranda. The omission of such notice, however, does not absolve the Owner from his responsibility to comply with LR's survey requirements for maintenance of class, all of which are available to Owners on the ClassDirect Live website.

3.8 Withdrawal/Suspension of class

3.8.1 When the class of a ship, for which the Regulations as regards surveys on hull, equipment and machinery have been complied with, is withdrawn by the Committee in consequence of a request from the Owner, the notation 'Class withdrawn at Owner's request' (with date) will be assigned.

3.8.2 When the Regulations as regards surveys on the hull, equipment or machinery have not been complied with and the ship is thereby not entitled to retain class, the class will be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation will be assigned.

3.8.3 Class will be automatically suspended and the Certificate of Class will become invalid if the Annual or Intermediate Survey has not been completed within the prescribed range or the due date of the survey.

3.8.4 Class will be automatically suspended from the expiry date of the Certificate of Class in the event that the Special Survey has not been completed by the due date and an extension has not been agreed (*see* 3.5.8), or is not under attendance by the Surveyors with a view to completion prior to resuming trading.

3.8.5 When, in accordance with 3.4.3 of the Regulations, a condition of class is imposed, this will be assigned a due date for completion and the ship's class will be subject to a suspension procedure if the condition of class is not dealt with, or postponed by agreement, by the due date.

3.8.6 When it is found, from the reported condition of the hull or equipment or machinery of a ship, that an Owner has failed to comply with Regulations 1.1.5, 3.4.1 or 3.4.5, the class will be liable to be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation assigned. When it is considered that an Owner's failure to comply with these requirements is sufficiently serious, the suspension or withdrawal of class may be extended to include other ships controlled by the same Owner, at the discretion of the Committee.

3.8.7 When it is found that a ship is being operated in a manner contrary to that agreed at the time of classification, or is being operated in environmental conditions which are more onerous or in areas other than those agreed by the Committee, the class will be liable to be automatically withdrawn or suspended.

3.8.8 Where a ship has been detained following a intervention by local authorities on two or more occasions in a two year period, with serious deficiencies found, then the class will be liable to be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation will be assigned. In these cases, a period of notice, not exceeding 3 months, may be given prior to any suspension or withdrawal of class.

3.8.9 In all instances of class withdrawal or suspension, the assigned notation, with date of application, will initially appear in the *Register Book*. In cases where class has been suspended by the Committee and it becomes apparent that the Owners are no longer interested in retaining LR's Class, the notation will be amended to withdrawn status. After class withdrawn status has been established in the *Register Book* for one year, it will be automatically amended to 'Classed LR until' (with date).

3.8.10 For reclassification and reinstatement of class, *see* 3.3.2.

3.9 Appeal from Surveyors' recommendations

3.9.1 If the recommendations of LR's Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Committee who may direct a Special Examination to be held.

3.10 Force majeure

3.10.1 If due to circumstances reasonably beyond the Owner's or LR's control, as defined below, the ship is not in a port when surveys become overdue the Committee may allow the ship to sail, in class, directly to an agreed discharge port and then, if necessary, in ballast to an agreed repair facility at which the survey can be completed. In this context 'Force Majeure' means damage to the ship, unforeseen inability of Surveyors to attend the ship due to governmental restrictions on right of access or movement of personnel, unforeseen delays in port or inability to discharge cargo due to unusually lengthy periods of severe weather, strikes, civil strife, acts of war or other force majeure.

3.11 Ownership details

3.11.1 It is the responsibility of each Owner to inform LR in writing of any change to its contact details and in the event of a ship sale to supply details of the new Owners. If the new Owner of a ship cannot be properly identified and the contact details established then the class of that ship will be specially considered by the Committee.

■ *Section 4*
Type Approval/Type Testing/ Quality Control System

4.1 LR Type Approval – Marine application

4.1.1 LR Type Approval is an impartial certification system that provides independent third-party Type Approval Certificates attesting to a product's conformity with specific standards or specifications. It is based on design review and type testing or where testing is not appropriate, a design analysis.

4.1.2 The LR Type Approval System is a process whereby a product is assessed in accordance with a specification, standard or code to check that it meets the stated requirements and through selective testing demonstrates compliance with specific performance requirements. The testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under approval. Thereafter, the producer is required to be able to use Quality Control procedures and processes to ensure that each item delivered is in conformity with that which has been Type Approved.

4.1.3 The selective testing required by 4.1.2 is to include environmental testing applicable to the product's installation on board a vessel classed or intended to be classed with LR.

4.1.4 LR Type Approval does not remove the requirements for inspection and survey procedures required by the Rules for equipment to be installed in ships classed or intended to be classed with LR. Also, LR Type Approval does not remove the requirement for plan appraisal of a system that incorporates Type Approved equipment where required by the Rules.

4.1.5 LR Type Approval is subject to the understanding that the producer's recommendations and instructions for the product and any relevant requirements of the Rules for the Classification of Inland Waterway Ships are fulfilled.

4.1.6 The producer supplying equipment or components under Quality Control procedures and processes is to have a recognised quality management system certified by an IACS member or Notified Body. The Quality Control procedures and processes are to address the production of the product consistent with 5.3.

4.1.7 Where equipment or components have been Type Approved in accordance with specifications and procedures other than LR's, details of the product, certification and testing are to be submitted for consideration where appropriate.

4.2 Type testing

4.2.1 Type testing is an impartial process that provides independent third-party verification that an item of machinery or equipment has satisfactorily undergone a functional type test.

4.2.2 Type testing is carried out against defined performance and test standards for a defined period of time with test conditions varying between minimum and maximum declared design conditions.

4.2.3 Type testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under assessment.

4.2.4 After type testing, mechanical equipment is to be opened out and inspected for damage or excessive wear.

4.2.5 On application from the manufacturer, type tests may be waived for equipment and machinery that has been proven to be reliable in marine service and where compliance with the current applicable standards can be demonstrated. Equipment and machinery that has been previously type tested with satisfactory testing evidence and certification need not have the type tests repeated where the previous testing is in compliance with the current testing standards for the equipment.

4.2.6 The acceptance of type testing certification is subject to the understanding that the manufacturer's recommendations and instructions for the product and any relevant requirements of the applicable Rules are fulfilled.

4.3 Quality Control System

4.3.1 A quality control system for the purposes of LR acceptance of materials and machinery refers to a scheme that covers the operational techniques and activities that is used to demonstrate that the quality requirements for a product are in accordance with declared standards.

4.3.2 The quality control system for a particular product extends to all parties involved in the supply chain from manufacture and testing through to delivery of the product.

4.3.3 LR acceptance of machinery and equipment manufactured under a quality control scheme is dependent on the scheme being maintained through a traceable process involving planned audits and spot inspections at the discretion of LR Surveyors. The purpose of the audits and spot inspections is to ensure that the procedures for manufacture and quality control are being maintained in a satisfactory manner.

4.3.4 The use of a quality control system does not remove the requirements for inspection processes that may be required by the Rules applicable to the equipment being supplied with a manufacturer's certificate. Also the use of a quality control system does not remove the requirement for plan appraisal of equipment or systems where required by the Rules.

■ *Section 5*
Classification of machinery with [✠]LMC or MCH notation

5.1 General

5.1.1 After delivery of machinery and equipment with the manufacturer's certificate to the shipyard, Survey at the Shipyard and Periodical Surveys are to be in accordance with the requirements for ships built or accepted into class with the ✠**LMC** notation.

5.2 Appraisal and records

5.2.1 To facilitate survey and compilation of classification records, the same plans and information required for a ship being accepted into class with the ✠**LMC** notation are to be submitted for the alternative notations **[✠]LMC** or **MCH,** for appraisal and information. Plans are not required where machinery and equipment has previously been type approved; in these cases it is only necessary to submit details of the machinery and equipment together with details of the previous approval.

5.3 Survey and inspection

5.3.1 The manufacturer's certificate for acceptance of machinery and equipment for assignment of the **[✠] LMC** or **MCH** notation is to be in the English language and include the following information:
(a) Design and manufacturing standard(s) used.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during design, manufacture and testing.
(d) Details of any type approval or type testing.
(e) Details of installation and testing recommendations for the machinery or equipment.

The manufacturer is to have a recognised quality management system certified by an IACS member or a Notified Body.

5.3.2 The installation and testing of machinery and equipment at the build yard which has been supplied with a manufacturer's certificate is to be in accordance with the requirements applicable to a ship having the **[✠]LMC** notation.

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in Ch 2,3.5. The periods between such surveys are as follows:

(a) Annual Surveys as required by Ch 2,3.5.1 or Ch 2,3.5.2.
(b) Intermediate Surveys at intervals of 30 months, *see* Ch 2,3.5.3.
(c) Special Surveys at 5-yearly intervals, *see* Ch 2,3.5.4 and Ch 2,3.5.8.
(d) Complete Surveys of machinery at 5-yearly intervals, *see* Ch 2,3.5.10 and Ch 2,3.5.14.

1.1.2 For the frequency of surveys of boilers, steam pipes, screwshafts, tube shafts, propellers and inert gas systems, *see* Sections 13 to 16.

1.2 Surveys for damage or alterations

1.2.1 At any time when a ship is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the propulsion or auxiliary machinery, including boilers, insulation or fittings, and tanks not forming part of the ship's structure, are removed for any reason, the steel structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or covering on decks is removed, the plating in way is to be examined before the cement or covering is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that LR has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.3.2 In the event of significant damage or defect affecting any ship, LR reserves the right to perform unscheduled surveys of the hull or machinery of other similar ships classed by LR and deemed to be vulnerable.

1.4 Definitions

1.4.1 A **Tanker** is a self-propelled ship or a non-propelled ship (barges) which is constructed generally with integral tanks and is intended primarily to carry liquids in bulk. (*See* Pt 4, Ch 4).

1.4.2 A **Bulk Carrier** is a self-propelled ship or a non-propelled ship (barge) intended for the carriage of heavy cargoes. (*See* Pt 4, Ch 1).

1.4.3 A **Container Ship** is a self-propelled ship or a non-propelled ship (barge) intended for the carriage of containers. (*See* Pt 4, Ch 1).

1.4.4 A **Chemical Tanker** is a self-propelled ship or a non-propelled ship (barge) constructed generally with integral tanks and being double hull construction, used primarily for the carriage in bulk of chemicals. (*See* Pt 4, Ch 4 and Ch 6).

1.4.5 A **Gas Tanker** is a cargo ship designed, constructed and used for the carriage in bulk of liquefied gases or other products of a flammable nature. (*See* Pt 4, Ch 4 and Ch 5).

1.4.6 A **Ballast Tank** is a tank which is used solely for the carriage of water ballast.

1.4.7 **Spaces** are separate compartments such as holds and tanks.

1.4.8 An **Overall Survey** is a survey intended to report on the overall condition of the hull structure and to determine the extent of additional Close-up Surveys.

1.4.9 A **Close-up Survey** is a survey where the details of structural components are within the close visual inspection range of the Surveyor, i.e. normally within reach of hand.

1.4.10 A **Transverse Section** includes all longitudinal members such as plating, longitudinals and girders at the deck, side, bottom, inner bottom, inner side, hopper side, top wing side and longitudinal bulkhead, where fitted. For transversely framed ships, a transverse section includes adjacent frames and their end connections in way of transverse sections.

1.4.11 **Representative Spaces** are those which are expected to reflect the condition of other spaces of similar type and service and with similar corrosion prevention systems. When selecting representative spaces, account is to be taken of the service and repair history on board and identifiable Critical Structural Areas.

1.4.12 **Critical Structural Areas** are locations which have been identified from calculations to require monitoring or from the service history of the subject ship or from similar ships or sister ships, if applicable, to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the ship.

1.4.13 **A Corrosion Prevention System** is normally considered a full hard protective coating. This is usually to be an epoxy coating or equivalent. Other systems (e.g. soft coatings) may be considered acceptable as alternatives provided they are applied and properly maintained in compliance with the manufacturer's specification.

1.4.14 **Coating Condition** is defined as follows:

GOOD condition with only minor spot rusting affecting not more than 20 per cent of areas under consideration, e.g. on a deck transverse, side transverse, on the total area of platings and stiffeners on the longitudinal structure between these components, etc.

FAIR condition with local breakdown at edges of stiffeners and weld connections and/or light rusting affecting 20 per cent or more of areas under consideration.

POOR condition with general breakdown of coating affecting 20 per cent or more of areas under consideration or hard scale affecting 10 per cent or more of area under consideration.

1.4.15 A **Prompt and Thorough Repair** is a permanent repair completed at the time of survey to the satisfaction of the Surveyor, therein removing the need for the imposition of any associated condition of class.

1.4.16 **Special consideration** or **specially considered** (in connection with close-up surveys and thickness measurements) means sufficient close-up inspection and thickness measurements are to be taken to confirm the actual average condition of the structure under the coating.

1.4.17 **Air pipe heads** installed on the exposed decks are those extending above the freeboard deck or superstructure decks.

1.4.18 The **Cargo Area** or **Cargo Length Area** is that part of the ship which contains all cargo holds and adjacent areas including fuel tanks, cofferdams, ballast tanks and void spaces. For oil tankers and chemical tankers, the **Cargo Area** is that part of the ship which contains cargo tanks, slop tanks and cargo/ballast pump-rooms, cofferdams, ballast tanks and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the ship over the above mentioned spaces.

1.5 Preparation for survey and means of access

1.5.1 Tanks and spaces are to be safe for access, i.e. gas freed, ventilated and illuminated.

1.5.2 In preparation for survey, thickness measurements and to allow for a thorough examination, all spaces are to be cleaned including removal from surfaces of all loose accumulated corrosion scale. Spaces are to be sufficiently clean and free from water, scale, dirt, oil residues, etc., to reveal corrosion, deformation, fractures, damages or other structural deterioration. However, those areas of structure whose renewal has already been decided by the owner need only be cleaned and descaled to the extent necessary to determine the limits of renewed areas.

1.5.3 Sufficient illumination is to be provided to reveal corrosion, deformation, fractures, damages or other structural deterioration.

1.5.4 Means are to be provided to enable the Surveyor to examine the structure in a safe and practical way.

1.5.5 For surveys, including close-up survey where applicable, in cargo spaces and ballast tanks, one or more of the following means of access, is to be provided:ss is to be provided:

(a) Permanent staging and passages through structures.
(b) Temporary staging and passages through structures.
(c) Lifts and movable platforms.
(d) Boats or rafts.
(e) Portable aldders may be used, at the discretion of the Surveyor.

1.5.6 Where soft coatings have been applied, safe access is to be provided for the Surveyor to verify the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating. When safe access cannot be provided, the soft coating is to be removed.

1.5.7 A survey planning meeting is to be held prior to the commencement of Intermediate Survey and Special Survey.

1.6 Repairs

1.6.1 Any damage in association with wastage over the allowable limit (including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the ship's structural, watertight or weathertight integrity, is to be promptly and thoroughly repaired. Areas to be considered include, (where fitted):

- side shell frames, their end attachments and adjacent shell plating;
- deck structure and deck plating;
- bottom structure and bottom plating;
- side structure and side plating;
- inner bottom structure and inner bottom plating;
- inner side structure and inner side plating;
- watertight or oiltight bulkheads;
- hatch covers and hatch coamings.

For locations where adequate repair facilities are not available, consideration may be given to allow the ship to proceed directly to a repair facility. This may require discharging the cargo and/or temporary repairs for the intended voyage.

1.6.2 Additionally, when a survey results in the identification of structural defects or corrosion, either of which, in the opinion of the Surveyor, will impair the ship's fitness for continued service, remedial measures are to be implemented before the ship continues in service.

■ *Section 2* Annual Survey – Hull requirements

2.1 Preparation

2.1.1 The ship is to be arranged and prepared for examination as required by 2.2 or 2.3, where applicable.

2.1.2 The ship is to be dry-docked or placed on a slipway, between the second and third year after the date of build or the last Special Survey, for examination in accordance with 3.2.3 to be carried out concurrently with the periodical load line inspection, where practicable.

2.2 Examination and testing for ships which are to be subjected to Annual Surveys as set out in Ch 2,3.5.1

2.2.1 The Surveyor is to satisfy himself as to the efficient condition of the following:

(a) Hatchways on freeboard and superstructure decks, ventilator and air pipe coamings, exposed casings, skylights, deckhouses and companionways, superstructure bulkheads, side scuttles and deadlights, together with all closing appliances.
(b) Means of ensuring weathertightness of steel hatch covers by hose test if deemed necessary.
(c) Scuppers and sanitary discharges with valves; guard rails and bulwarks; freeing ports, gangways and life-lines.
(d) Freeboard marks; Steering arrangements.
(e) Vent piping, including that of inert gas installations, where applicable, within the cargo tank area, together with associated flame arresters and pressure/vacuum valves, also cargo and bunker deck piping of tankers.

2.2.2 On tankers of Type G, C and N, *see* Pt 4, Ch 4, 5 and 6, when submitted for the survey required by 2.1.2, pumprooms and the electrical installation are also to be inspected, including verification of:

(a) The efficiency of any safe type equipment fitted.
(b) The insulation resistance.
(c) Tests are to be carried out to demonstrate the effectiveness of earth bonding straps, where fitted.

Inert gas installations are to be examined in accordance with Section 16.

2.3 Examination and testing for ships which are subjected to Annual Surveys as set out in Ch 2,3.5.2

2.3.1 Surveyors are to examine the ship afloat in light condition internally and externally, as far as necessary in order to satisfy themselves as to the efficient condition of the hull structure.

2.3.2 Should examination afloat give rise to doubts as to the condition of the underwater structure or of tanks and cofferdam spaces, it may be necessary for Surveyors to require the ship to be dry-docked or placed on a slipway for a more detailed inspection.

2.3.3 Where the ship is placed in dry-dock or on a slipway, Surveyors are to examine the shell plating, the sternframe, rudder(s), etc., and attention is to be given to those underwater parts of the ship particularly liable to deterioration due to excessive corrosion or to damage by contact with other vessels, quaywalls or from causes such as chafing, touching or lying on the ground and to any undue unfairness of bottom plating especially in transversely framed ships.

2.3.4 Surveyors are to satisfy themselves as to the efficient condition of the following, where applicable:

(a) Hatchways with beams and covers, deckhouses and companionways together with any closing appliances.
(b) Scuppers and sanitary discharges so far as practicable, bulwarks and guard rails.

2.3.5 Surveyors are to examine the steering arrangements. The various parts of the auxiliary steering gear are to be assembled to ascertain that the gear is in good and workable condition. Auxiliary steering gear of the mechanically driven type is to be examined and tested to demonstrate that, if the power for the main steering gear fails, the auxiliary gear can be put into operation immediately.

2.3.6 Surveyors are to examine and test bow rudder installations when they are an essential part of the steering arrangement. Opening up the gear may be required if deemed necessary by Surveyors in view of the condition or the testing of the gear.

2.3.7 When chain cables are ranged, the anchors and cables are to be examined by the Surveyors.

2.3.8 Surveyors are to satisfy themselves as to the efficient condition of the fire protection, detection and extinguishing arrangements so far as applicable.

■ *Section 3* Intermediate Survey – Hull requirements

3.1 Preparation

3.1.1 The ship is to be brought into light condition for internal and external examination afloat.

3.1.2 The following ships are to be examined in dry-dock or on a slipway:
(a) Ships which are rivetted below the light waterline.
(b) Ships over 20 years old.
In the case of ships over 20 years old and not rivetted below the light waterline this requirement may be waived if following an internal examination the Surveyor is satisfied as to the efficient condition of the underwater part of the shell.

3.1.3 When the ship is in dry-dock or on a slipway, it is to be at a sufficient height above the dock floor or the ground for examination of shell plating, sternframe, rudder(s), etc. If necessary proper staging is to be erected for this examination. On side slipways it may be required to remove cradles for examination of the bottom plating. Each rudder is to be lifted for examination of pintles if considered necessary by the Surveyor.

3.1.4 The decks, hatchways with beams and covers are to be cleared for examination.

3.1.5 The steering gear and auxiliary steering gear are to be prepared for examination and testing.

3.1.6 Tankers of Type G, C and N, *see* Pt 4, Ch 4, when submitted for the survey required by 2.1.2, are to be thoroughly cleared of gas.

3.1.7 Stream anchor, when provided, to be prepared for examination and testing.

3.2 Examination and testing

3.2.1 The Surveyor is to examine the ship afloat in light condition internally and externally, for so far as necessary in order to satisfy himself as to the efficient condition of the hull structure.

3.2.2 Should examination afloat give rise to doubts as to the condition of the underwater structure or of tanks and cofferdam spaces, it may be necessary for the Surveyor to require the ship to be dry-docked or placed on a slipway for a more detailed inspection.

3.2.3 When the ship is placed in dry-dock or on a slipway, the Surveyor is to examine the shell plating, the sternframe, rudder(s), etc., and attention is to be given to those underwater parts of the ship particularly liable to deterioration due to excessive corrosion or to damage by contact with other vessels, quaywalls or from causes such as chafing, touching or lying on the ground and to any undue unfairness of bottom plating especially in transversely framed ships.

3.2.4 The Surveyor is to satisfy himself as to the efficient condition of the following, where applicable:
(a) Hatchways with beams and covers, deckhouses and companionways together with any closing appliances.
(b) Scuppers and sanitary discharges so far as practicable, bulwarks and guard rails.
(c) Wheelhouse elevation arrangements.

3.2.5 The Surveyor is to examine the steering arrangements. The various parts of the auxiliary steering gear are to be assembled to ascertain that the gear is in good and workable condition. Auxiliary steering gear of the mechanically driven type is to be examined and tested to demonstrate that, if the power for the main steering gear fails, the auxiliary gear can be put into operation immediately.

3.2.6 Where rod and chain steering gear is fitted, attention is to be paid to all parts of rod and chain gears. All pins are to be examined and the chain in the vicinity of the blocks is to be cleaned and examined for wear and tear. Any length of chain so worn that its mean diameter at its most worn part is reduced by 11 per cent or more from its Rule diameter, is to be renewed. All replacements of chains are to be subjected, at a recognized Proving Establishment, to the proof tests required for short link cables by Chapter 10 of the *Rules for the Manufacture, Testing and Certification of Materials* , and the certificates are to be produced. It is recommended that, in addition, a breaking test be applied to these chains.

3.2.7 It is recommended that repaired chains be tested by the repairers and a certificate to that effect produced.

3.2.8 The Surveyor is to examine and test bow rudder installations when they are an essential part of the steering arrangement. Opening up the gear may be required if deemed necessary by the Surveyor in view of the condition or the testing of the gear.

3.2.9 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor.

3.2.10 The Surveyor is to satisfy himself as to the efficient condition of the fire protection, detection and extinguishing arrangements so far as applicable.

3.2.11 On tankers of Type G, C and N Closed and N open with flame screens, *see* Pt 4, Ch 4, 5 and 6, pump-rooms, cargo, bunker and vent piping systems on deck and in pump-rooms, pressure/vacuum valves and flame arresters and the electrical installation are also to be inspected, including verification of:
(a) The efficiency of any safe type equipment fitted.
(b) The insulation resistance.

(c) Tests are to be carried out to demonstrate the effectiveness of earth bonding straps, where fitted.

Inert gas installations are to be examined in accordance with Section 16.

■ *Section 4* Special Survey – Hull requirements

4.1 Preparation

4.1.1 The ship is to be placed in dry-dock or on a slipway, cleaned and be at a sufficient height above the dock floor or the ground for examination of shell plating, sternframe, rudder(s), etc. If necessary proper staging is to be erected for this examination. On side slipways it may be required to remove cradles for examination of the bottom plating. Each rudder is to be lifted for examination of pintles if considered necessary by the Surveyor.

4.1.2 The holds, peaks, deep and wing tanks, engine and boiler spaces, and other spaces, are to be cleared and cleaned as necessary, and the bilges and limbers all fore and aft are to be cleaned and prepared for examination as required by 4.2. Platform plates in engine and boiler spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, close and spar ceiling, lining and pipe casings are to be removed for examination of the structure.

4.1.3 In ships having a single bottom, a sufficient amount of close ceiling is to be lifted on each side from the bottom and bilges to permit the structure below to be examined.

4.1.4 In ships having a double bottom, a sufficient amount of ceiling is to be removed from the bilges and inner bottom to enable the condition of the plating to be ascertained. If it is found that the plating is clean and in good condition, and free from rust, the removal of the remainder of ceiling may be dispensed with. The Surveyor may waive the removal of heavy reinforced compositions if there is no evidence of leakages, cracking or other faults in the composition.

4.1.5 The steelwork is to be exposed and cleaned as may be required for its proper examination by the Surveyor.

4.2 Examination and testing

4.2.1 The requirements of an Intermediate Survey are to be complied with, *see* Section 3.

4.2.2 All items and spaces required to be cleared and cleaned for examination by 4.1 are to be examined. Careful examination is to be made of parts of the structure particularly liable to excessive corrosion, or to deterioration from causes such as chafing, lying on the ground, or handling of cargo.

4.2.3 The Surveyor may require to gauge, by drilling or other approved means, the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or materially reduced in scantlings are to be made good by materials of approved scantlings and quality. Attention is to be given to the structure in way of discontinuities. Surfaces are to be re-coated as necessary.

4.2.4 In cases where the inner surface of the bottom plating is covered with cement, asphalt, or other composition, the removal of this covering may be dispensed with, provided that it is inspected, tested by beating or chipping, and found sound and adhering satisfactorily to the steel.

4.2.5 Double bottom compartments, peak tanks and all other tanks are to be tested by a head sufficient to give the normal maximum pressure that can be experienced in service. Tanks may be tested afloat provided that their internal examination is also carried out afloat. Tanks forming part of the main structure, except as stated below, are to be cleaned and examined internally, special attention being given to tanks under boiler spaces. Tanks (excluding peak tanks) used exclusively for oil fuel or fresh water in ships less than 15 years old need not be examined internally, provided that, after external examination and testing in accordance with the requirements set out above, the Surveyor finds the condition of these compartments satisfactory.

4.2.6 Spaces which are inaccessible for examination, e.g. low double bottom tanks, boxed in webframes, or spaces under tanks not forming part of the ship's structure are to be examined externally and gauged as necessary. In case of doubt, openings are to be made in the structure for examination of the interior so that the Surveyor can satisfy himself as to the efficient condition of the structure.

4.2.7 All decks, casings and superstructures are to be examined. Attention is to be given to the corners of openings and other discontinuities in way of strength decks and top sides.

4.2.8 Wood decks or sheathing are to be examined. If decay or rot is found or the wood is excessively worn, the wood is to be renewed. Attention is to be given to the condition of the plating under wood decks, sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating. *See also* 1.2.1.

4.2.9 The anchors are to be examined. If the chain cables are ranged they are to be examined. Chain cables of ships over 10 years old are to be ranged at each Special Survey. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 11 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined.

4.2.10 The Surveyor is to satisfy himself that there are suitable mooring ropes and a towline when these are a Rule requirement.

4.2.11 The steering gear, and its connections and control systems (main and alternative) are to be examined. The various parts of the auxiliary steering gear are to be assembled, examined and tested. The helm indicator is to be examined and tested.

4.2.12 The hand pumps, suctions, watertight doors, air and sounding pipes are to be examined.

4.2.13 The Surveyor is to satisfy himself as to the efficient condition of the following:

(a) Means of escape from: machinery spaces, crew and passenger spaces, and spaces in which crew are normally employed.
(b) Means of communication between: bridge and engine-room control station.
(c) Fire protection, detection and extinction.

4.2.14 For surveys of machinery, electrical equipment, boilers, steam pipes, screwshafts and inert gas systems, *see* Sections 10 to 16.

4.3 Thickness measurements

4.3.1 The general minimum requirements for thickness measurements for all ship types are given in Table 3.4.1. The Surveyor may extend the thickness measurements as deemed necessary.

4.3.2 Thickness measurements may be carried out in the 12 months proceeding the due date of the Special Survey or when SS postponed in the 12 months proceeding the revised SS due date.

4.3.3 In areas where substantial corrosion (defined as wastage of individual plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits), has been noted, then additional measurements are to be carried out, as deemed necessary by the attending Surveyor.

4.3.4 Where substantial corrosion is identified and not rectified, this will be subject to re-examination and gauging as necessary at Intermediate Surveys.

4.3.5 At each Special Survey, thickness measurements are to be taken in way of critical areas, as considered necessary by the Surveyor. Critical areas are to include locations throughout the ship that show substantial corrosion and/or considered prone to rapid wastage or erosion.

Table 3.4.1 Thickness Measurements - All ship types

<table>
<tr><th>Special Survey I
(Ships 5 years old)</th><th>Special Survey II
(Ships 10 years old)</th><th>Special Survey III
(Ships 15 years old)</th><th>Special Survey IV
(Ships 20 years old)</th></tr>
<tr><td>Critical areas , as required by the Surveyor</td><td>Within the cargo length area or 0,5L amidships:
- selected deck plates
- one transverse section
- selected bottom/inner bottom plates
- selected side shell plates
- selected hatch covers and coamings, see Note 1
- Critical areas, as required by the Surveyor</td><td>Within the cargo length area or 0,5L amidships:
- each exposed deck plate
- two transverse sections
- selected tank top plates
- each bottom/inner bottom plates
- all side shell plates
- selected transverse and longitudinal cargo hold bulkheads, see Note 1
- all hatch covers and coamings, see Note 1
- Critical areas, as required by the Surveyor</td><td>Within the cargo length area or 0,5L amidships:
- each deck plate
- three transverse sections, see Note 3
- each bottom/inner bottom/tank top plate
- all side shell plates
- all transverse and longitudinal cargo hold bulkheads, see Note 1
- all hatch covers and coamings, see Note 1
- Critical areas, as required by the Surveyor</td></tr>
<tr><td></td><td></td><td>Outside the cargo length area:
- selected deck plates
- selected side shell plates
- selected bottom plates
- nozzle plating in way of transverse thrust units</td><td>Outside the cargo length area:
- each deck plate
- each side shell plate
- each bottom plate
- nozzle plating in way of transverse thrust units</td></tr>
<tr><td></td><td colspan="2">Collision bulkhead, forward machinery space bulkhead, aft peak bulkhead, see Notes 1 & 2</td><td>All transverse and longitudinal bulk heads outside cargo hold area, see Notes 1 & 2</td></tr>
<tr><td></td><td colspan="3">In engine room , see Note 2:
- sea chests
- sea water cross over manifold
- duct keel or pipe tunnel plating and internals</td></tr>
<tr><td></td><td></td><td colspan="2">Selected internal structure such as ballast tank, floor and longitudinals, transverse frames, web frames, deck beams, girders, etc.</td></tr>
<tr><td colspan="4">NOTES
1. Including plates and stiffeners.
2. Measurements may be waived or reduced after satisfactory visual examination, when such bulkheads form the boundaries of dry void spaces or river chests, etc. are found in good condition.
3. The number of transverse sections may be reduced at the Surveyor’s discretion for vessels of length under 40 m.
4. In case of original tank coating being in good condition, scope of TM may be reduced at the Surveyor’s discretion.
5. In case of detected areas with substantial corrosion, extent of corrosion should be verified by means of 5 point pattern over 1 m² area.</td></tr>
</table>

4.3.6 Where a 10 per cent area reduction of deck plating and longitudinals is exceeded, a check of the buckling capacity of the upper-deck is to be carried out for all tankers.

■ *Section 5* Special Survey of ships over 15 years old – Hull requirements

5.1 Preparation

5.1.1 The requirements of 4.1 are to be complied with.

5.1.2 A sufficient amount of ceiling in the holds and other spaces is to be removed from the bilges and inner bottom to enable the condition of structure in the bilges, the inner bottom plating, pillar feet, and the bottom plating of bulkheads to be examined. If the Surveyor deems it necessary, the whole of the ceiling is to be removed.

5.1.3 In ships having a single bottom, the limber boards and ceiling equal to not less than three strakes, all fore and aft on each side are to be removed, one such strake being taken from the bilges and one along the centre keelson. Where the ceiling is fitted in hatches, the whole of the hatches and at least one strake of ceiling in the bilges are to be removed. If the Surveyor deems it necessary the whole of the ceiling and limber boards are to be removed.

5.1.4 The chain locker is to be cleaned internally. The chain cables are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection.

5.2 Examination and testing

5.2.1 The requirements of 4.2 are to be complied with.

5.2.2 All items and spaces required to be cleared and cleaned for examination by 5.1 are to be examined.

5.3 Determination of thickness

5.3.1 The requirements of 4.3 are to be complied with at Special Survey III (Ships 15 years old) and at each SS thereafter.

■ *Section 6* Special Survey of tankers – Hull requirements

6.1 General

6.1.1 The requirements of Sections 4 and 5 are to be complied with as applicable.

6.1.2 The survey is to include the inspection of pump-rooms, cargo, bunker and vent piping systems on deck and in pump-rooms, and also pressure/vacuum valves and flame arresters.

6.2 Preparation and inspection of tanks

6.2.1 Attention is to be given to the inside of the bottom plating in order to ensure that there is no excessive pitting of the plating. When extensive pitting is found, care is to be taken to preserve the longitudinal and local strength of the bottom by the requisite renewals or repairs.

6.2.2 When bottom plating and bulkheads in way of strums of cargo suction pipes cannot be properly visually examined, the strums are to be removed for access.

6.2.3 The condition of internal coatings if applied is to be examined.

6.3 Testing

6.3.1 All cargo tanks are to be tested by filling the tanks with water to the top of the hatch coaming. Cofferdams and cargo tanks of tankers of Type G, C and N, *see* Pt 4, Ch 4, 5 and 6, are to be pressure tested with water to the top of the hatch coaming at uneven special surveys (first, third, fifth and so forth). At even special surveys (second, fourth, sixth and so forth) the tanks are to be pressure tested in accordance with the requirements of Table 1.7.2 in Pt 3, Ch 1.

6.3.2 Tanks may be tested when the ship is afloat, provided that the internal examination of the bottom is also carried out afloat.

6.3.3 Where extensive repairs have been effected to the shell plating or bulkheads, the tanks are to be tested to the Surveyor's satisfaction.

6.4 Determination of thickness

6.4.1 The requirements of 4.3 are to be complied with at Special Survey II (Ships 10 years old).

■ *Section 7* Special Survey of tankers with cargo tanks independent from the ship's structure – Hull requirements

7.1 General

7.1.1 The requirements of Sections 4 and 5 and of 6.1.2, 6.2.2 and 6.2.3 are to be complied with so far as applicable.

7.2 Preparation and inspection

7.2.1 Special attention should be paid to the ship's structure underneath the cargo tanks and the supports, securing arrangements, etc., of these tanks.

7.3 Testing

7.3.1 All cargo tanks are to be tested by filling the tanks with water to the top of the hatch coaming. Cofferdams and cargo tanks of tankers of Type G, C and N, *see* Pt 4, Ch 4, 5 and 6, are to be pressure tested with water to the top of the hatch coaming at uneven special surveys (first, third, fifth and so forth). At even special surveys (second, fourth, sixth and so forth) the tanks are to be pressure tested in accordance with the requirements of Table 1.7.2 in Pt 3, Ch 1.

7.4 Determination of thickness

7.4.1 The requirements of 4.3 are to be complied with for the hull structure at Special Survey II (ships 10 years old) and at each SS thereafter. Cargo tanks independent from the ship's structure are to be gauged, by drilling or other approved means, to determine the amount of general diminution in thickness. The gauging is to be done in at least one place on each tank (in two places on each tank over 20 m in length) in each strake of bottom, forward and aft side and top plating. The remainder of the plating is to be gauged as deemed necessary by the Surveyor taking into account the results of gauging already carried out.

■ *Section 8*
Ships for liquefied gases under pressure and/or partially refrigerated

8.1 General

8.1.1 The requirements of Sections 2 to 6 are to be complied with as applicable.

8.1.2 For requirements of Special Survey for electrical equipment, *see* Section 12.

8.2 Intermediate Surveys – Basic requirements

8.2.1 Cargo liquid level indicating devices are to be generally examined. The low level, high level and overfill alarms are to be examined and tested to ascertain that they are in working order. Consideration will be given to the acceptance of simulated tests provided that they are carried out at the cargo temperature and/or pressure.

8.2.2 Where applicable, gas leakage systems are to be examined and tested to ascertain that they are in working order and calibrated using sample gas.

8.2.3 Where applicable, the correct functioning of the cargo containment system temperature indicating equipment, together with any associated alarms, is to be verified.

8.2.4 Where applicable, the ventilation system for the spaces surrounding the cargo tanks and in working spaces is to be examined and checked for satisfactory operation.

8.2.5 Where applicable, inert gas systems for the environmental control of cargo tanks and/or spaces surrounding the cargo tanks are to be generally examined.

8.2.6 Where applicable, control devices for the cargo containment system and cargo handling equipment, together with any associated shutdown and/or interlock, are to be checked under simulated working conditions, and if required, recalibrated.

8.2.7 The arrangements for manually operated emergency shutdown are to be checked to ascertain they are in working order.

8.2.8 Cargo pipelines, valves and fittings are to be generally examined, with special reference to expansion bellows, supports and vapour seals on insulated pipes.

8.2.9 Portable and/or fixed drip trays, or insulation for deck protection in the event of cargo leakage are to be examined for their condition.

8.3 Intermediate Surveys – Refrigerating equipment

8.3.1 Where refrigerating equipment for cargo temperature and pressure control is fitted, the following are to be examined so far as practicable:

(a) The machinery under working condition.
(b) Shells of all pressure vessels in the system including primary refrigerant gas and liquid pipes, cargo vapour and liquid condensate pipes and condenser cooling arrangements. Insulation need not be removed, but any deterioration or evidence of dampness is to be investigated.

8.4 Special Surveys – General requirements

8.4.1 The requirements of 8.1 to 8.3 are to be complied with so far as applicable.

8.4.2 All cargo tanks are to be examined internally and externally so far as practicable, particular attention being paid to the plating in way of supports and of securing arrangements and pipe connections.

8.4.3 Where cargo tanks are insulated and the insulation accessible, the insulation should be examined externally and sections removed for examination of the tank if considered necessary by the Surveyor.

8.4.4 The Surveyor may require to gauge, by drilling or other approved means, the thickness of the material in any portion of the cargo tank structure where sign of wastage is evident, wastage is normally found or where there is doubt as to the condition of the structure in way of insulation. Any parts of the cargo tank structure which are found defective or materially reduced in scantlings are to be made good by materials of approved scantlings and quality.

8.4.5 Cargo tank internal pipes and fittings are to be examined, and all valves and cocks in direct communication with the interiors of tanks are to be opened out for inspection. Connection pipes are to be examined internally, so far as practicable.

8.4.6 Pressure relief valves and vacuum relief valves are to be opened out for inspection and are to be adjusted afterwards. Valves may be removed from tanks, cargo gas and liquid pipelines for this purpose.

8.4.7 All cargo pumps, cargo booster pumps and cargo vapour pumps, where applicable, are to be opened out for examination.

8.4.8 Where considered necessary by the Surveyor, insulated cargo gas and liquid pipelines are to have sections of insulation removed to ascertain the condition of the pipes.

8.4.9 Where equipment for the production of inert gas is fitted, it is to be examined and tested to show it to be operating satisfactorily within the gas specification limits. Pipelines, valves, etc., for the distribution of the inert gas are to be generally examined. Pressure vessels for the storage of inert gas are to be examined internally together with their fastenings. Pressure relief valves are to be demonstrated to be in good working order. Liquid nitrogen storage vessels are to be examined as far as practicable and all control equipment, alarms and safety devices are to be verified as operational.

8.5 Special Surveys – Refrigerating equipment

8.5.1 Each reciprocating compressor is to be opened out. Cylinder bores, pistons, piston rods, connecting rods, valves and seats, glands, relief devices, suction filters and lubricating arrangements are to be examined. Crankshafts are to be examined but crankcase glands and the lower half of main bearings need not be exposed if the Surveyor is satisfied with the alignment and wear.

8.5.2 Where other than reciprocating type compressors are fitted, or where there is a program of replacement instead of surveys on board, alternative survey arrangements will be considered. Each case will be given individual consideration.

8.5.3 The water end covers of condensers are to be removed for examination of the tubes, tubeplates and covers.

8.5.4 Refrigerant condenser cooling water pumps, including standby pump(s) which may be used on other services, are to be opened out for examination.

8.5.5 Where a pressure vessel is insulated, sufficient insulation is to be removed, especially in way of connections and supports, to enable the vessel's condition to be ascertained.

8.5.6 Insulated pipes are to have sufficient insulation removed to enable their condition to be ascertained. Vapour seals are to be specially examined for condition.

8.5.7 The Surveyor is to satisfy himself that all pressure relief valves and/or safety discs throughout the system are in good order. No attempt, however, is to be made to test primary refrigerant pressure relief valves on board ship.

8.6 Special Surveys of ships over 10 years old

8.6.1 The requirements of 8.1 to 8.5 are to be complied with so far as applicable.

8.6.2 All pressure vessels of inert gas installations are to be examined internally and externally and tested.

8.6.3 Cargo tanks are to be pressure tested to a pressure of 1,25 times the working pressure.

8.7 Determination of thickness of tank plating

8.7.1 In addition to the requirements of 4.3 and 8.4.4, determination of thickness of cargo tank plating is to be carried out at each Special Survey by drilling or other approved means, to determine the amount of any general diminution. The gauging is to be carried out in at least two places of the bottom, forward and aft tank plating, side and top plating. The remainder of the plating is to be gauged as deemed necessary by the Surveyor taking into account the results of gauging already carried out.

■ *Section 9*
Dredgers, hopper dredgers, sand carriers, hopper barges and reclamation craft

9.1 General

9.1.1 The requirements of this Section are to be complied with, as applicable, in addition to the survey requirements of Sections 2 to 5. Where surveys are required on dredging or hopper equipment such as gantries, bottom doors and their operating gear, positioning spuds and suction pipe attachments, these will be limited to the extent considered necessary by the Surveyor to satisfy himself that their condition or malfunction will not adversely affect the ship's structure.

9.1.2 When the ship is placed in dry-dock or on a slipway, the Surveyor is to examine the hopper doors or hopper valves, ladders, spudwells, and their fittings where applicable.

9.2 Special Surveys

9.2.1 On ships under 10 years old:

(a) Hoppers are to be cleared and cleaned as necessary and examined.
(b) Where applicable, hopper doors or valves are to be opened and closed, so far as is practicable, but keel blocks need not normally be moved specially to permit this to be done.
(c) The integrity of hopper overflows and diluting water inlet and distribution structures are to be confirmed. Weir valves and sluices are to be tested to ensure proper operation, particular attention being paid to the lower weir, when weirs are fitted at more than one level.
(d) Attention is to be given to shell plating in way of hopper overflows.
(e) The attachment to the ship's structure of all main items of dredging equipment, including gantries, 'A' frames and spud control gear supports, is to be carefully examined to ensure that no fracture is present.

9.2.2 On ships over 10 years old:

(a) Attention is to be given by the Surveyor to the structure in way of dredging pumps.
(b) Hopper doors and valves are to be checked for proper operation, and their hinges, control gear and other fittings are to be examined for wear or distortion. All seals and weardown strips are to be replaced if necessary, but a watertight seal is not normally required. Attention is to be paid to areas likely to be suffering from excessive erosion.
(c) Those items of dredging gear and equipment whose efficiency is not part of classification but whose failure or malfunctioning is, nevertheless, likely to adversely affect the ship's structure, are to be examined to ensure that the structural integrity of the ship is maintained.

9.3 Determination of thickness

9.3.1 The requirements of 4.3 are to be complied with at Special Survey II (Ships 10 years old) and at each SS thereafter.

■ *Section 10* Machinery surveys – General requirements

10.1 Annual Surveys

10.1.1 In ships which are to be subjected to Annual Surveys as set out in Ch 2,3.5.1 and are placed in dry-dock or on a slipway, *see* 2.1.2, the propeller(s), sternbush(es), water inlets and outlets and gratings are to be examined. The clearance in each sternbush or the efficiency of each sterngland is to be ascertained.

10.1.2 In ships which are subject to Annual Surveys as set out in Ch 2,3.5.2 the Surveyor is to generally inspect the machinery spaces with particular attention being given to the following:

(a) Propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards.
(b) Emergency escape routes are to be checked to ensure that they are free of obstruction.
(c) The bilge pumping system, including operation of extended spindles and level alarms, where fitted. Satisfactory operation of the bilge pumps is to be proven.
(d) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel oil supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.

10.1.3 For additional requirements for tankers, *see* 2.2.2.

10.1.4 The main propulsion, essential auxiliary and emergency generators including safety arrangements, controls and foundations are to be generally examined. Surveyors are to confirm that Periodical Surveys of engines have been carried out as required by the Rules and that safety devices have been tested.

10.1.5 For ships fitted with automation equipment for main propulsion, essential auxiliary and emergency machinery, a general examination of the equipment and arrangements is to be carried out. Records of changes to the hardware and software used for control and monitoring systems for propelling and essential auxiliary machinery since the original issue (and their identification) are to be reviewed by the attending Surveyor. Satisfactory operation of the safety devices and control systems is to be verified.

10.1.6 For ships fitted with an electronically controlled engine for main propulsion, essential auxiliary and emergency power purposes the following is to be carried out to the satisfaction of the Surveyor:

(a) A general examination of the electronic control system and associated parts.
(b) Verification of evidence of satisfactory operation of the engine and where possible this is to include a running test under load.
(c) Verification of satisfactory operation of the safety devices and control systems.
(d) Verification that any changes to hardware and software for control of the engine have been submitted and approved by LR.
(e) Verification that any changes to control and monitoring arrangements that affect the operation of the engine have been submitted and approved by LR.
(f) Verification that where changes have been carried out, there is evidence of acceptance tests and trials for Programmable Electronic Systems which include confirmation of software life cycle activities appropriate to the stage in the system's life cycle at the time of system examination.
(g) Identification and verification that the key monitoring parameters/sensors are in working order.

10.2 Intermediate Surveys

10.2.1 In ships which are placed in dry-dock or on a slipway for this survey, the propeller(s), sternbush(es), water inlets and outlets and gratings are to be examined. The clearance in each sternbush or the efficiency of each sterngland is to be ascertained.

10.2.2 The machinery installation is to be generally examined and tried under full load working conditions. If the results of the trials are satisfactory, the Surveyor may waive opening up of the machinery.

10.2.3 For additional requirements for tankers, *see* 3.2.11.

10.2.4 For ships fitted with a classed dynamic positioning system, the control system and associated machinery items are to be generally examined under working conditions.

10.3 Complete Survey of machinery

10.3.1 When the ship is in dry-dock or on a slipway, the propeller(s), sternbush(es), water inlets and outlets and gratings are to be examined. The clearance in each sternbush or the efficiency of each oil gland is to be ascertained.

10.3.2 All shafts (except screwshafts and tube shafts for which special arrangements are detailed in Section 15), thrust block(s) and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and weardown can be established and found within acceptable limits.

10.3.3 An examination is to be made of all reduction gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and integral clutch arrangements. Toothed parts and clutches may be checked through inspection doors. Opening up may be required by the Surveyor in view of the condition of certain components.

10.3.4 The following auxiliaries and components are to be examined under working conditions:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.

(b) Steering machinery.

(c) Windlass(es) and associated driving equipment, where fitted. Opening up may be required by the Surveyor depending upon the trial results or the condition of certain components.

10.3.5 The holding down bolts and chocks of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings are to be examined.

10.3.6 All air receivers for essential services, together with their mountings, valves and safety devices are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

10.3.7 The valves, cocks and strainers of the bilge system are to be opened up as considered necessary by the Surveyor and together with pipes, are to be examined and tested under working conditions. The oil fuel, feed, lubricating oil and cooling water systems, also the ballast connections and blanking arrangements to deep tanks which may carry liquid or dry cargoes, together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

10.3.8 Fuel tanks which do not form part of the ship's structure are to be examined and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally before the ship is 15 years old if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all fuel tanks are to be examined, so far as practicable.

10.3.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

10.3.10 In addition to the requirements of 10.3.1 to 10.3.9, detailed requirements for oil engines, electrical installations and boilers are given in Sections 11, 12 and 13 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Surveyor will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking into account design, appropriate indicating equipment and operational records.

10.3.11 For tankers the cargo vapour detection and alarm systems are to be examined, calibrated and tested to demonstrate that they are in good working order. Upper-deck cargo loading and discharge pipe lines are to be subjected to a pressure test of 1,1 times the approved maximum working pressure with a minimum of 10 Bar.

10.3.12 For ships that are provided with wheelhouse elevation arrangements, these arrangements are to be examined and tested to the extent as considered necessary by the Surveyor.

10.3.13 On vessels fitted with a classed dynamic positioning system, the control system and associated machinery items are to be examined and tested under working conditions.

■ *Section 11*
Oil engines – Detailed requirements

11.1 Complete Surveys

11.1.1 The requirements of 10.3 are to be complied with as far as is applicable.

11.1.2 The following parts are to be opened out and examined, but *see also* 10.3.10:

Cylinders, covers, valves and valve gear, pistons, piston rods, crossheads, guides, connecting rods, crankshafts and all bearings, bedplates, crankcase door fastenings and explosion relief devices, scavenge blowers, superchargers and their associated coolers, air compressors and their intercoolers, filters and/or separators and safety devices, fuel pumps and fittings, camshaft drives, torsional vibration dampers or detuners, flexible couplings, clutches, reverse gears, attached pumps and cooling arrangements.

11.1.3 Selected pipes in the starting air system are to be removed for internal examination and are to be hammer-tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

11.1.4 The electric starting system, if fitted, is to be examined and tested.

11.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

■ *Section 12*
Electrical equipment

12.1 Complete Surveys

12.1.1 A test for insulation resistance is to be made on the cables, switchgear, generators, motors, heaters, lighting fittings, etc., and the insulation resistance is to be not less than 100 000Ω between all insulated circuits and earth. The installation may be subdivided to any desired extent by opening switches, removing fuses or disconnecting appliances for the purpose of this test. The readings of the insulation resistance test are to be recorded.

12.1.2 The fittings on main and emergency switchboards, section boards and sub-distribution fuse boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

12.1.3 Generator, switchgear and associated equipment are to be tested, so far as practicable, to verify that protective devices operate satisfactorily.

12.1.4 The electric cables are to be examined, so far as is practical, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by 12.1.1. Tests are to be carried out to demonstrate the effectiveness of earth bonding straps, where fitted.

12.1.5 The generator prime movers are to be surveyed as required by Section 11 and the governing of the engine tested. The motors concerned with essential services together with associated control and switchgear are to be examined and if considered necessary, are to be operated, so far as practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

12.1.6 Navigation light systems including indicators and associated alarms if fitted, are to be examined and tested.

12.1.7 In passenger ships, the emergency source of power and its associated circuits and where fitted, the temporary source of power and its automatic arrangements are to be tested.

12.1.8 If on cargo ships an emergency source of power has been fitted, this system and its associated circuits are to be tested.

12.1.9 Electrical equipment such as cables and certified safe type of equipment fitted in dangerous zones and spaces on tankers intended for the carriage of flammable gases and/or liquids is to be examined. Tests are to be carried out to demonstrate the effectiveness of earth bonding straps, where fitted.

12.1.10 Battery compartments, lockers and boxes together with their ventilation compartments are to be examined.

12.2 Annual and Intermediate Surveys

12.2.1 In ships which are subjected to Annual Surveys as set out in Ch 2,3.5.2 the electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled, they should be tested in the automatic mode.

12.2.2 For special requirements for tankers, *see* 2.2.2 and/or 3.2.11.

■ *Section 13* Boilers

13.1 Frequency of surveys

13.1.1 All boilers, thermal oil and hot water units intended for essential services, together with boilers used exclusively for non-essential services having a working pressure exceeding 3,5 bar and a heating surface exceeding 4,5 m^2 are to be surveyed internally. There is to be a minimum of two internal examinations during each five-year Special Survey cycle or six year cycle (when SS has been postponed). The interval between any two such examinations is not to exceed 36 months. A general external examination is to be carried out at the time of the Annual Survey on ships subjected to AS.

13.1.2 Consideration may be given in exceptional circumstances to an extension of the internal examination of the boiler not exceeding three months beyond the due date. The extension may be granted after the following is satisfactorily carried out:
(a) External examination of the boiler.
(b) Examination and operational test of the boiler safety valve relieving gear (easing gear).
(c) Operational tests of the boiler protective devices.
(d) Review of the following records since the previous boiler survey:
- Operation;
- Maintenance;
- Repair history;
- Feedwater chemistry.

In this context 'exceptional circumstances' means unavailability of repair facilities, essential materials, equipment or spare parts.

13.2 Scope of surveys

13.2.1 At the surveys described in 13.1 the boilers are to be examined internally and externally and where considered necessary, the pressure parts are to be tested by hydraulic pressure and the thickness of plates and tubes and sizes of stays are to be ascertained to determine a safe working pressure. The principal mountings on boilers are to be opened up and examined, and the safety valves are to be set under steam to a pressure not greater than the approved design pressures of the respective parts. As a working tolerance, the setting is acceptable provided that the valves lift at not more than 103 per cent of the approved design pressure. The remaining mountings are to be examined externally and if considered necessary by the Surveyor, are to be opened up for internal examination. Collision chocks, rolling stays and boiler stools are to be examined and maintained in an efficient condition.

13.2.2 In fired boilers employing forced circulation, the pumps used for this service are to be opened and examined at each Boiler Survey.

13.2.3 The oil fuel burning system is to be examined under working conditions and a general examination made of fuel tank valves, pipes, deck control gear and oil discharge pipes between pumps and burners.

■ *Section 14* Steam pipes

14.1 Frequency of surveys

14.1.1 Steam pipes are to be surveyed 10 years after the date of build and subsequently at every Special Survey.

14.2 Scope of surveys

14.2.1 At each survey, a selected number of steam pipes over 76 mm external diameter and with bolted joints, are to be removed for internal examination and are to be hydraulically tested to 1,5 times the working pressure. If these selected pipes are found satisfactory in all respects, the remainder need not be tested. So far as practicable, the pipes are to be selected for examination and hydraulic test in rotation so that in the course of surveys all sections of the pipeline will be tested.

14.2.2 Where steam pipes of the category described in 14.2.1 have welded joints between lengths of pipe and/or between pipes and valves, the lagging in way of the welds is to be removed, the welds examined, and if considered necessary by the Surveyor, crack-detected. Pipe ranges having welded joints are to be hydraulically tested to 1,5 times the working pressure. Where lengths having ordinary bolted joints are fitted in such pipe ranges and can be readily disconnected, they are to be removed for internal examination and hydraulically tested to 1,5 times the working pressure.

14.2.3 At the surveys specified in 14.1.1, any copper or copper alloy pipes, such as those having expansion or other bends, which may be subjected to bending and/or vibration, are to be annealed before being tested.

■ *Section 15* Screwshafts, tube shafts and propellers

15.1 Frequency of surveys

15.1.1 All screwshafts are to be surveyed at intervals of five years.

15.1.2 When directional propellers for main propulsion purposes are fitted, they are to be opened up for examination of the working parts and control gear at intervals of five years.

15.2 Scope of surveys

15.2.1 All screwshafts and tube shafts are to be withdrawn at the intervals prescribed in 15.1.1 for examination by LR's Surveyors.

15.2.2 Controllable pitch propellers are to be surveyed at the same time as the screwshafts. The working parts and control gear are to be opened up for examination.

■ Section 16
Inert gas systems

16.1 Frequency of surveys

16.1.1 The whole inert gas installation is to be surveyed at intervals of 2½ years. For all ships having a Service extension notation, the survey is to be carried out concurrently with the examination in dry-dock or on the slipway, *see* 2.1.2, and at the Special Survey. For all other ships, the survey is to be carried out at every Intermediate and Special Survey.

16.2 Scope of surveys

16.2.1 The inert gas system including alarms and safety devices, is to be tested to demonstrate that it is in good working condition, to the satisfaction of the Surveyors.

■ Section 17
Classification of ships not built under survey

17.1 General

17.1.1 When classification is desired for a ship not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

17.1.2 Periodical Surveys of such ships, when classed, are subsequently to be held as in the case of ships built under survey.

17.2 Hull and equipment

17.2.1 Plans showing the main scantlings and arrangements of the actual ship, together with any proposed alterations, are to be submitted for approval. These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the ship.

17.2.2 In all cases, the full requirements of Section 4 are to be carried out. Ships over 15 years old are, in addition, to comply with the requirements of Section 5. In the case of tankers the requirements of Sections 6, 7 or 8 are also to be carried out.

17.2.3 During the survey, the Surveyors are to satisfy themselves regarding the materials, the workmanship and verify the approved scantlings and arrangements. For this purpose, and in order to ascertain the amount of any deterioration, parts of the structure will require to be gauged as necessary. Particulars of the anchors, chain cables and equipment are to be submitted. Fire protection, detection and extinction are to be in accordance with the Rules, *see* Pt 6, Ch 3. Ships of recent construction will receive special consideration.

17.3 Machinery

17.3.1 To facilitate the survey, plans of the following items (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of the boilers, air receivers and important forgings, are to be furnished with:

- General pumping arrangements, including air and sounding pipes.
- Pumping arrangements at the forward and after ends of ships carrying liquefied gases or liquids in bulk and drainage of cofferdams and pump-rooms.
- General arrangement of cargo piping in tanks and on deck of ships carrying liquefied gases or liquids in bulk.
- Vapourlines of cargo tanks, with information of type, capacity and set pressures of the pressure/vacuum valves, should be submitted for consideration for tankers of Type I, II, IIA, III and IIIA.
- Ventilation arrangement of cargo and/or ballast pump-rooms and other enclosed spaces which contain cargo handling equipment.
- Bilge, ballast and oil fuel pumping arrangements in the machinery space, including the capacities of the pumps on bilge service.
- Arrangement of oil fuel pipes.
- Arrangement of oil fuel piping in connection with oil burning installations.
- Arrangement drawings of oil fuel service and other tanks not forming part of the ship's structure, fiittings on settling and service tanks and their heating coils need not be submitted, provided the construction is to the Surveyor's satisfaction.
- Arrangement of compressed air systems and cooling water systems for main and auxiliary essential services.
- Oil fuel and cargo oil overflow systems, where these are fitted.
- Boiler feed systems and streamlines.
- Boilers which operate at a pressure greater than 3,4 bar (3,5 kgf/mm^2).
- Air receivers.
- Line of shafting.
- Stearing gear.
- Where the ship has been in service for a length of time greater than five years, plans of clutch and reversing gear and reduction gearing need not be submitted provided they are of a type of design accepted by LR or manufactured to a recognized National or International Standard.
- Plans of the propeller (including spare propeller, if supplied) need not be submitted provided the propeller has been manufactured in a manner acceptable to LR.
- Electrical circuits.

17.3.2 Plans additional to those detailed in 17.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification.

17.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

17.3.4 For new ships and ships which have been in service less than five years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for ships constructed under Special Survey. For older ships, the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

17.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

17.3.6 The screwshaft is to be drawn and examined.

17.3.7 The steam pipes are to be examined and tested as required by Section 14.

17.3.8 The bilge, ballast and oil fuel pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

17.3.9 Oil burning installations are to be examined as required at Complete Surveys and found, or modified, to comply with the requirements of the Rules; they are also to be tested under working conditions.

17.3.10 The electrical equipment is to be examined as required at Complete Surveys.

17.3.11 The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

17.3.12 Where classification is desired for a ship which is classed by another recognized Society, special consideration will be given to the scope of the survey.

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RULES FOR THE MANUFACTURE, TESTING AND CERTIFICATION OF MATERIALS

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Materials

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■ *Section 1* Scope

1.1 General

1.1.1 Materials used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by Lloyd's Register (hereinafter refered to as LR), are to be manufactured, tested and inspected in accordance with these Rules.

1.1.2 Wrought, cast and extruded materials are to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapters 3 to 9 of these Rules. Mooring and anchoring equipment is to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapter 10. Manufacturers of these materials must be approved by LR according to the requirements in Sections 2 or 3. Only those materials within a manufacturer's scope of approval may be used.

1.1.3 Welding consumables are to comply with the requirements of Chapter 11 of these Rules.

1.1.4 Where welding is used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by LR, welding qualifications and tests shall be performed according to Chapter 12 of these Rules. All welding shall be performed according to Chapter 13 of these Rules.

1.1.5 Plastics materials are to comply with the requirements of Chapter 14 of these Rules.

1.1.6 The materials and components which are to comply with these requirements for the purposes of classification are defined in the relevant Rules dealing with design and construction.

■ *Section 2* Approval and survey requirements

2.1 Approval and survey requirements – General

2.1.1 Marine materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be made at works which have been approved by LR for the type and grade of product being supplied.

2.1.2 Materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be manufactured, tested and inspected under Survey according to the requirements of one of the following two schemes:
(a) The Materials Survey Scheme, *see* 2.3.
(b) The Materials Quality Scheme, *see* 2.4.

2.1.3 For the purposes of survey, LR Surveyors are to be allowed access to all relevant parts of the works, and are to be provided with the necessary facilities and information to enable them to verify that the manufacture is being carried out in accordance with the approved procedures. Facilities are also to be provided for the selection of test material, the witnessing of mechanical tests and the examination of materials, as required by these Rules.

2.1.4 Where a production process, testing or examination of materials is sub-contracted, this must be with the approval of LR. Surveyors are to be allowed access to the sub-contractor's premises in order to conduct Surveys according to the requirements of these Rules.

2.1.5 Products manufactured in accordance with Chapters 11 and 14 are to be approved in accordance with the requirements therein. For these materials, approval is given for a specific product on a type approval basis, rather than the approved manufacturer/survey arrangements applied to materials covered by Chapters 3 to 10.

2.2 LR Approval – General

2.2.1 Unless specifically stated in other Chapters of these Rules, all LR approvals apply to materials used in applications intended for marine service, as described in 1.1.

2.2.2 The procedures for application for approval of manufacturers and products, the details of the information to be supplied by the manufacturer, and the test programme to be conducted on the products are given in the appropriate book of LR's *Materials and Qualification Procedures for Ships* (MQPS). This is published in the CD Live section of LR's web site at http://www.lr.org.

2.2.3 LR publishes lists of approved manufacturers and approved products. The lists are published in the CD Live section of LR's website, http://www.lr.org. They are also available on the CD-ROM version of the *Rules and Regulations for the Classification of Ships* available from LR. The lists are as follows:

- *List of Approved Manufacturers of Materials*.
- *Approved Welding Consumables for Use in Ship Construction*.
- *Lists of Paints, Resins, Reinforcements and Associated Materials*.
- *Lists of Approved Anchors*.

2.2.4 For initial LR approval as an Approved Manufacturer for a particular material, the manufacturer is required to demonstrate to the satisfaction of LR that the necessary manufacturing and testing facilities are available, and are supervised by suitably qualified personnel. A specified programme of tests is to be carried out under the supervision of LR Surveyors, and the results are to be to the satisfaction of LR.

2.2.5 If the results of the initial assessment of the manufacturer, and the test programme are considered satisfactory, the manufacturer will be added to the list of approved manufacturers of materials, and a certificate of approval will be issued to the manufacturer by LR, showing the scope of materials and grades covered by the approval. Initial approval will generally be under the Materials Survey Scheme, *see* 2.3.

2.2.6 Approved manufacturers who meet the entry requirements may apply for approval under the Materials Quality Scheme, *see* 2.4.

2.2.7 When a manufacturer has more than one works, the manufacturer's approval shall only be valid for the works where the test programme was conducted.

2.2.8 It is the manufacturer's responsibility to advise LR of all changes to the manufacturing process parameters that may affect the application of the material, prior to the adoption of the changes in production. Additional approval tests may be required to maintain the approval.

2.2.9 Maintenance of approval is dependent on the manufacturer continuing to meet the requirements of the applicable sections of these Rules.

2.2.10 Where it is considered that an approved manufacturer is not maintaining its responsibilities to comply with these Rules, the approval may be suspended by LR until such time that agreed corrective and preventive actions are considered to have been satisfactorily carried out. If considered necessary, LR may require that the normal level of testing and inspection is increased.

2.2.11 In all instances, LR will reduce the scope of, or withdraw approval from, a manufacturer where it becomes apparent that the manufacturer is unable to maintain compliance with these Rules or the scope of approval.

2.2.12 Where a manufacturer disagrees with any decisions made with regard to LR approval, they may appeal in writing to LR.

2.2.13 Any documents, data or other information received as part of the approval process will be treated as strictly confidential, and will not be disclosed to any third party, without the manufacturer's prior written consent.

2.3 Materials Survey Scheme

2.3.1 Materials according to Chapters 3 to 10 of these Rules and produced under the Materials Survey Scheme will be subject to Direct Survey by an LR Surveyor. The scheme requires the Surveyor to survey and certify all materials according to the requirements of these Rules.

2.3.2 Approved manufacturers are to request a survey of the material by an LR Surveyor, when required. Manufacturers must provide the Surveyor with details of the order, specification and any special conditions additional to the requirements of these Rules.

2.3.3 All mechanical tests required by these Rules are to be witnessed. The Surveyor may allow part of this task to be carried out by a member of the works staff by prior written agreement.

2.3.4 Before final acceptance, all materials are to be submitted to the specified tests and examinations under conditions acceptable to the Surveyor. The results are to comply with the Rules, and all materials are to be to the satisfaction of the Surveyor.

2.3.5 The specified tests and examinations are to be carried out prior to the despatch of finished materials from the manufacturer's works. Where materials are supplied in the rough or unfinished condition, as many as possible of the specified tests are to be carried out by the manufacturer, and any tests or examinations that are not completed are to be carried out under survey at a subsequent stage of manufacture.

2.3.6 In the event of any material proving unsatisfactory during subsequent working, machining or fabrication, such material is to be rejected, notwithstanding any previous certification.

2.3.7 In addition to witnessing test results, the Surveyor is responsible for ensuring that the manufacturing process, inspection, testing, identification and certification are properly conducted. As part of the Materials Survey Scheme, regular visits will be made to all relevant parts of the works to check for compliance against the requirements of these Rules, and to ensure that the manufacturer is maintaining the capability to consistently produce approved materials.

2.3.8 The Surveyor, when satisfied that the material fully meets the requirements of these Rules, will certify the material in accordance with Section 3 and the appropriate Chapter of these Rules.

2.3.9 For a manufacturer to maintain approval under this scheme, the works will be subject to a periodic inspection of all relevant parts of the works, at intervals not exceeding three years. The procedure for this periodic inspection is given in Book B of LR's *Materials and Qualification Procedures for Ships* (MQPS). This periodic inspection is in addition to the regular visits made according to 2.3.7.

2.4 Materials Quality Scheme

2.4.1 The manufacturer may apply to be approved under the Materials Quality Scheme where the following requirements are met:

(a) The manufacturer has been approved by LR for a minimum of three years; and
(b) The manufacturer has a quality management system, which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum; and
(c) The manufacturer has a satisfactory history of quality performance in the manufacture and supply of LR approved materials.

2.4.2 Special consideration may be given to manufacturers who have not been approved under the Materials Survey Scheme, and may be considered onto the Materials Quality Scheme providing:

(a) They have a quality management system which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum.
(b) They can demonstrate a history of satisfactory supply of materials which LR deems to be equivalent to those for which approval under the Materials Quality Scheme is requested.

In this case, the initial assessment of the manufacturer will include the product testing regime, as required for initial approval under the Materials Survey Scheme (*see* 2.2.4).

2.4.3 The Scheme is based on a Scheme Certification Schedule, made between LR and each individual manufacturer. The schedule will stipulate:

(a) The scope of approved products covered by the approval.
(b) The process route applied by the manufacturer for each approved product.
(c) The arrangements for LR scheme, audits, including scope, frequency, schedule, etc.
(d) Agreed procedures for certification of approved materials.
(e) Information to be supplied periodically to LR by the manufacturer.
(f) Procedures for the use of the scheme mark.

2.4.4 The contents of the Scheme Certification Schedule are to remain confidential between LR and the manufacturer.

2.4.5 The Materials Quality Scheme is based on a technical audit approach, and is designed to complement the quality management systems audits performed to ISO 9001. The role of the Surveyor in scheme audits is to:

(a) Verify that the quality management system is being maintained and audited to the requirements of ISO 9001.
(b) Verify that the requirements of these Rules are being implemented.
(c) Verify that the requirements of this Scheme are being implemented.
(d) Perform Scheme audits, which focus on the technical aspects of the product realisation process, particularly with regard to Rule requirements.
(e) Perform witness testing as required.
(f) Verify the data supplied to LR periodically by the manufacturer as part of the Scheme requirements.

2.4.6 The Materials Quality Scheme may be applied to any approved manufacturer who meets the eligibility requirements, and who applies to be approved under the scheme. If approved under the scheme, the manufacturer's name will appear on the List of Approved Manufacturers published by LR, with an indication that they are approved under this scheme.

2.4.7 The scheme is available to manufacturers producing approved materials according to Chapters 3 to 10 of these Rules.

2.4.8 The procedures for application for approval for the Materials Quality Scheme are given in Book M of LR's *Materials and Qualification Procedures for Ships* (MQPS).

2.4.9 Where LR is satisfied that the manufacturer meets all of the requirements of the Scheme, and that it is appropriate for the products being manufactured, a Scheme Certification Schedule will be issued, which must be signed by an authorised representative of the manufacturer.

2.4.10 Once the Scheme Certification Schedule has been signed by both parties, LR will issue the manufacturer with a certificate of approval according to the Materials Quality Scheme.

2.4.11 Maintenance of approval will be according to the Scheme Certification Schedule agreed between LR and the manufacturer, and these Rules.

2.4.12 It is the responsibility of the attending Surveyor to perform regular Scheme audits at the manufacturer's works in accordance with the Scheme Certification Schedule, and the requirements of these Rules.

2.4.13 It is not the intention to repeat the audit according to ISO 9001 conducted by the recognised certification body. The Surveyor is, however, to be satisfied that these audits are being conducted effectively. Where appropriate, the Surveyor may conduct a partial audit to ISO 9001 to verify this.

2.4.14 Witness tests may be conducted as part of the Scheme audit. This will involve the selection of material, and the witness of sampling and testing according to the requirements of the appropriate chapter of these Rules. Such witness testing may be on LR grades, or materials which the Surveyor deems to be equivalent (for the purposes of audit testing only).

2.4.15 Once every three years, a full assessment of scheme compliance will be conducted by a Surveyor who is not the regular attending Surveyor.

2.4.16 In the event of any change which means that the manufacturer no longer meets the requirements for the Materials Quality Scheme (for example the loss of ISO 9001 approval), the Scheme certificate of approval will be revoked. The manufacturer will revert to the Materials Survey Scheme, and will be subject to survey according to that scheme.

■ *Section 3*
Certification of materials

3.1 General

3.1.1 All materials subject to these Rules are to be supplied with appropriate certification, as required by the relevant requirements of these Rules. This will normally be an LR certificate or a manufacturer’s certificate validated by LR, although a manufacturer's certificate may be accepted where allowed by the relevant requirements of these Rules.

3.1.2 Manufacturers approved under the Materials Quality Scheme are licensed to apply the scheme mark to manufacturer's certificates according to the requirements of the scheme (*see* 2.4).

3.1.3 The following certificate types are to be used, (a) and (b) for the Materials Survey Scheme, and (d) for the Materials Quality Scheme:

(a) **LR Certificate**
This type of certificate is issued by LR based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules.

(b) **Manufacturer's certificate validated by LR**
A manufacturer's certificate, validated by LR on the basis of inspection and testing carried out on the delivered product in accordance with the requirements of these Rules may be accepted. In this case, the certificate will include the following statement:
"We hereby certify that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register."

(c) **Manufacturer's certificate**
This type of certificate is issued by the manufacturer based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules or the applicable National or International standard. The certificate is to be validated by the manufacturer's authorised representative, independent of the manufacturing department. The certificate will contain a declaration that the products are in compliance with the requirements of these Rules or the applicable National or International standard.

(d) **Manufacturer's certificate issued under the Materials Quality Scheme**
Where a manufacturer is approved according to the Materials Quality Scheme, they will issue manufacturer's certificates bearing the scheme mark. The certificates must also bear the following statement:
"This certificate is issued under the arrangements authorised by Lloyd's Register (operating group) in accordance with the requirements of the Materials Quality Scheme and certificate number MQS …….."

3.1.4 Where these Rules allow for the issue of a manufacturer's certificate for materials, either validated by an LR Surveyor, or bearing the Materials Quality Scheme mark, the manufacturer is to ensure that a copy of the certificate is supplied to LR.

3.2 Materials Survey Scheme

3.2.1 The requirements for certification of materials according to the Materials Survey Scheme are established by the relevant requirements of these Rules.

3.2.2 The manufacturer is to supply the surveyor with any additional customer order requirements that are in addition to the requirements of these Rules, when the request for the issue or validation of the certificate is made.

3.3 Materials Quality Scheme

3.3.1 Part of the certification schedule will include an agreement for the manufacturer to apply the scheme mark to manufacturer's certificates relating to approved products within the scope of approval of the manufacturer.

3.3.2 The use of the scheme mark is governed by the following:

(a) The use of the scheme mark is not transferable. It is only to be used in conjunction with the manufacturer and works name and location shown on the certificate of approval.

(b) The scheme mark must be applied to all manufacturers' certificates relating to approved materials produced under the Scheme.

(c) In no circumstances is the scheme mark to be applied to test certificates relating to non-approved products.

(d) The scheme mark is not to be used in any way which may imply approval for products which are not covered within the manufacturer's scope of approval.

(e) Where a manufacturer is removed or suspended from the scheme, use of the scheme mark must cease immediately.

3.3.3 The certificate as given in 3.1.3(d) is to be validated by an authorised representative of the manufacturer. The size and position of the scheme mark and statement on the manufacturer's certificate must be agreed by LR.

3.3.4 Where manufacturers are approved under this scheme, the manufacturer's certificate issued according to these requirements fully meets the materials certification requirements of these Rules.

3.4 Electronic certification

3.4.1 Where these Rules allow the issue of manufacturers' test certificates, under either the Materials Survey Scheme or the Materials Quality Scheme, these may be issued in electronic format provided that:

(a) All tests and inspections have been satisfactorily completed according to the requirements of these Rules.
(b) Procedures are in place to ensure that electronic certificates are only issued according to the requirements of these Rules.
(c) The certification system is subject to regular inspection by the attending Surveyor.
(d) A copy of the electronic certificate is supplied to LR. This copy will be deemed to be the original of the test certificate.

3.4.2 In addition to the requirements of 3.4.1, for items certified under the Materials Survey Scheme, the LR stamp and Surveyor's signature may be applied electronically by the Surveyor. This is only allowed where the Surveyor has access to the results of the relevant tests and inspections, and is able to authorise the production of the test certificate with their signature. The authorisation may be conducted electronically either at the manufacturers' works, or remotely.

3.4.3 If the Surveyor's stamp and signature are being applied electronically according to 3.4.2, then the manufacturer is to ensure that the Surveyor is provided with all relevant information regarding the customer order, when the request for authorisation is made.

■ *Section 4*
General requirements for manufacture

4.1 General

4.1.1 The following definitions are applicable to these Rules:

Item: A single forging, casting, plate, tube or other rolled product as delivered.

Piece: The rolled product from a single slab or billet or from a single ingot if this is rolled directly into plates, strip, sections or bars.

Batch: A number of similar items or pieces presented as a group for acceptance testing.

4.1.2 Where a manufacturer purchases semi-finished products (e.g. slabs) for the purpose of re-processing (e.g. rolling), the manufacturer is to ensure that the materials are from an LR approved manufacturer, and manufactured within the scope of approval of that manufacturer. The aim of chemical analysis, dimensions, surface and internal quality checks are to be agreed between the manufacturer and purchaser. The semi-finished materials must be supplied with appropriate certification, according to these Rules.

4.1.3 It is the responsibility of the manufacturer to ensure compliance with all relevant aspects of these Rules. All deviations are to be recorded as non-compliances, and brought to the attention of the Surveyor, along with corrective actions taken. Failure to do this is considered to render the material as not complying with these Rules.

4.1.4 The manufacturer is to maintain all test and inspection records required by these Rules for at least seven years. Records are to be made available to LR on request.

4.1.5 Where material is produced which does not meet all aspects of these Rules, the manufacturer may apply to LR for a concession to certify the material as approved. LR will consider each application on a case-by-case basis, although concession will only normally be granted in exceptional circumstances. If the concession is granted, a formal written numbered concession will be issued to the manufacturer. The concession number must be applied to the approval certificate, whether it is an LR certificate or a validated manufacturer's certificate.

4.2 Chemical composition

4.2.1 The ladle analysis used for certification purposes is to be determined after all alloying elements have been added and sufficient time allowed for such additions to equalize throughout the ladle.

4.2.2 The method of taking samples is to ensure that the reported analysis is representative of the cast. In addition, the manufacturer must determine and certify the chemical composition of every heat of material.

4.2.3 Where more than one sample is taken, the method of averaging for the final certificate result and the determination of acceptable variations in composition are to be agreed with the Surveyor.

4.2.4 The chemical composition of ladle samples is to be determined by the manufacturer in an adequately equipped and competently staffed laboratory. The manufacturer's analysis will be accepted, but may be subject to occasional independent checks if required by the Surveyor.

4.2.5 The analysis is to include the content of all the elements detailed in the relevant Sections of the Rules and, where appropriate, the National or International Standard applied.

4.2.6 At the discretion of the Surveyors, a check chemical analysis of suitable samples from products may also be required. These samples are to be taken from the material used for mechanical tests but, where this is not practicable, an alternative procedure for obtaining a representative sample is to be agreed with the manufacturer. For product samples, the permissible limits of deviation from the specified ladle analysis are to be in accordance with an appropriate International or National Standard specification.

4.3 Heat treatment

4.3.1 Materials are to be supplied in the condition specified in, or permitted by, the relevant Chapters of these Rules.

4.3.2 Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components which require heat treatment, alternative methods will be specially considered.

4.3.3 The manufacturer is to maintain the records, including the temperature charts of all heat treatments for at least seven years.

4.4 Test material

4.4.1 Sufficient test material is to be provided for the preparation of the test specimen detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

4.4.2 The test material is to be representative of the item or batch and is not to be separated until all the specified heat treatment has been completed, except where provision for an alternative procedure is made in subsequent Chapters of these Rules.

4.4.3 All test material is to be selected by the Surveyor or an authorized deputy and identified by suitable markings which are to be maintained during the preparation of the test specimens.

4.5 Mechanical tests

4.5.1 The dimensions, number and direction of test specimens are to be in accordance with the requirements of Chapter 2 and the specific requirements for the product.

4.5.2 Where Charpy impact tests are required, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Chapters. One individual value may be less than the required average value provided that it is not less than 70 per cent of that value.

4.5.3 In the Rules, mechanical properties are specified in SI units, but alternative units may be used for acceptance testing. In such cases, the specified values are to be converted in accordance with the appropriate conversions given in Table 1.4.1. It is preferred that test results be reported in SI units, but alternative units may be used provided that the test certificate gives, in the same units, the equivalent specification values.

Table 1.4.1 Conversions from SI units to metric and Imperial units

1 N/mm^2 or MPa	=	0,102 kgf/mm^2
1 N/mm^2 or MPa	=	0,0647 $tonf/in^2$
1 N/mm^2 or MPa	=	0,145 x 10^3 lbf/in^2
1J	=	0,102 kgf m
1J	=	0,738 ft lbs
1 kgf/mm^2	=	9,81 N/mm^2 or MPa
1 $tonf/in^2$	=	15,4 N/mm^2 or MPa
1 lbf/in^2	=	6,89 x 10^{-3} N/mm^2 or MPa
1 kgf m	=	9,81 J
1 ft lbf	=	1,36 J

4.6 Re-test procedures

4.6.1 Re-test procedures are to be in accordance with the requirements of Ch 2,1.4.

4.7 Visual and non-destructive examination

4.7.1 Prior to the final acceptance of materials, surface inspection, verification of dimensions and non-destructive examination are to be carried out in accordance with the requirements detailed in subsequent Chapters of these Rules.

4.7.2 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

4.7.3 When there is visible evidence to doubt the soundness of any material or component, such as flaws in test specimens or suspicious surface marks, the manufacturer is expected to prove the quality of the material by any suitable method.

4.8 Rectification of defective material

4.8.1 Small surface imperfections may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from defects and the rectification has been completed in accordance with any applicable requirements of subsequent Chapters of these Rules and to the satisfaction of the Surveyor.

4.8.2 The repair of defects by welding can be accepted only when permitted by the appropriate specific requirements and provided that the agreement of the Surveyor is obtained before the work is commenced. When a repair has been agreed, it is necessary in all cases to prove by suitable methods of non-destructive examination that the defects have been completely removed before welding is commenced. Welding procedures and inspection on completion of the repair are to be in accordance with the appropriate specific requirements and are to be to the satisfaction of the Surveyor.

4.8.3 Manufacturers wishing to carry out welding work must have at their disposal the necessary workshops, lifting gear, welding equipment, pre-heating, and where necessary annealing facilities and testing devices, as well as certified welders and supervisors to enable them to perform the work properly. Proof shall be furnished to the Surveyor that these conditions are satisfied before welding work begins.

4.9 Identification of materials

4.9.1 The manufacturer is to adopt a system of identification which will enable all finished materials to be traced to the original cast, and the Surveyors are to be given full facilities for tracing the material when required. When any item has been identified by the personal mark of a Surveyor, or his deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

4.9.2 Before any item is finally accepted it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements.

4.9.3 Hard stamping is to be used except where this may be detrimental to the material, in which case stencilling, painting or electric etching is to be used. Paints used to identify alloy steels are to be free from lead, copper, zinc or tin, i.e. the dried film is not to contain any of these elements in quantities of more than 250 ppm.

4.9.4 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

Section

■ *Section 1* General requirements for testing

1.1 Preparation of test specimens

1.1.1 The requirements specified below detail all the tests that may be applied to metallic materials. The specific tests and the test specimen types required for each material type, grade and product type are detailed in the subsequent Chapter of these Rules.

1.1.2 Where test material is cut from products by shearing or flame cutting, a reasonable margin is required to allow sufficient material to be removed from the cut edges during machining of the test specimens.

1.1.3 Test specimens are to be prepared in such a manner that they are not subjected to any significant work hardening, cold straining or heating during straightening or machining.

1.1.4 Test samples are not to be removed from the material they represent until heat treatment is complete. For castings in cases where test samples are separately cast, the castings and samples are to be heat treated together.

1.1.5 Dimensional tolerances are to comply with a relevant ISO specification.

1.2 Testing machines

1.2.1 All tests are to be carried out by competent personnel on machines of approved types. The machines are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. This calibration is to be carried out by a nationally recognized authority or other organization of standing and is to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house. The accuracy of test machines is to be within ± one per cent.

1.3 Discarding of test specimens

1.3.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine it may be discarded and replaced by a new test specimen prepared from material adjacent to the original test.

1.3.2 In addition to the discarding of test specimens as indicated in 1.3.1, a tensile test specimen may also be discarded when the specified minimum elongation is not obtained and the distance between the fracture and the nearest gauge mark is less than one-quarter of the gauge length.

1.4 Re-testing procedures

1.4.1 Where the result of any test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made. For acceptance of the material, satisfactory results are to be obtained from both of these additional tests.

1.4.2 Where the results from a set of three impact test specimens do not comply with the requirements, an additional set of three impact test specimens may be tested provided that, of the original set tested, not more than two individual values are less than the required average value and, of these, not more than one is less than 70 per cent of this average value. The results obtained are to be combined with the original results to form a new average which, for acceptance, is to be not less than the required average value. Additionally, for these combined results, not more than two individual values are to be less than the required average value and, of these, not more than one is to be less than 70 per cent of this average value.

1.4.3 The additional tests detailed in 1.4.1 and 1.4.2 are, where possible, to be made on material adjacent to the original samples. For castings, where insufficient material remains in the original test samples, the additional test may be made on other test samples representative of the castings. *See also* 1.3 for discarding of test specimens.

1.4.4 When unsatisfactory results are obtained from tests representative of a batch of material, the item or piece from which the tests were taken is to be rejected. The remainder of the material in the batch may be accepted provided that two further items or pieces are selected and tested with satisfactory results. If the tests from one or both or these additional items or pieces give unsatisfactory results, the batch is to be rejected.

1.4.5 When a batch of material is rejected, the remaining items or pieces in the batch may be resubmitted individually for test, and those which give satisfactory results may be accepted.

1.4.6 At the option of the manufacturer, rejected material may be resubmitted as another grade and may then be accepted, provided that the test results comply with the appropriate requirements.

1.4.7 When material which is intended to be supplied in the 'as-rolled' or 'hot-finished' condition fails test, it may be suitably heat treated and resubmitted for test. Similarly, materials supplied in the heat treated condition may be reheat treated and resubmitted for test. Unless otherwise agreed by the Surveyor, such reheat treatment is to be limited to one repeat of the final heat treatment cycle.

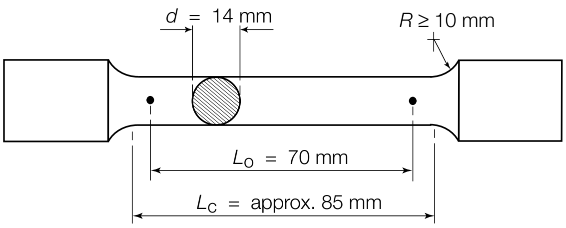
■ *Section 2* Tensile tests

2.1 Dimensions of test specimens

2.1.1 Proportional test specimens with a gauge length L_o of $5,65\sqrt{S_o}$ or $5d$, where S_o is the cross-sectional area, d the diameter and L_c the parallel test length, have been adopted as the standard form of test specimen, and in subsequent Chapters in these Rules the minimum percentage elongation values are given for test specimens of these proportions.

2.1.2 The gauge length may be rounded off to the nearest 5 mm provided that the difference between the adjusted gauge length and the calculated one is less than 10 per cent of the calculated gauge length.

2.1.3 For forgings and castings (excluding those in grey cast iron) proportional test specimens of circular cross-section are to be machined to the dimensions shown in Fig. 2.2.1.

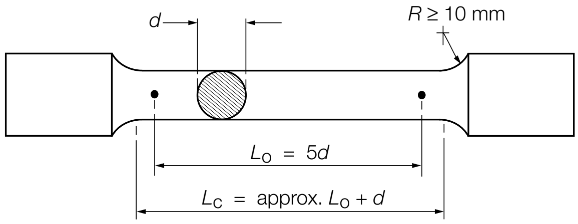


NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 20$ mm

Fig. 2.2.1
Test specimen dimensions for forgings and castings – I

2.1.4 For hot rolled bars and similar products, the test specimens are to be as in Fig. 2.2.1, except that for small sizes they may consist of a suitable length of bar or other product tested in the full cross-section.

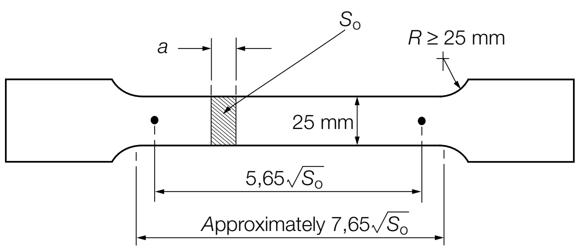
2.1.5 As an alternative to 2.1.3 and 2.1.4, proportional or non-proportional test specimens of other dimensions may be used, subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. Where the size of proportional test specimens is other than as shown in Fig. 2.2.1, the general dimensions are to conform with Fig. 2.2.2.



NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 1,5d$

Fig. 2.2.2
Test specimen dimensions for forgings and castings – II

2.1.6 For plates, strip and sections, the test specimens are to be machined to the dimensions shown in Fig. 2.2.3 or Fig. 2.2.4. Where the capacity of the available testing machine is insufficient to allow the use of a test specimen of full thickness, this may be reduced by machining one of the rolled surfaces. Alternatively, for materials over 40 mm thick, test specimens of circular cross-section machined to the dimensions shown in Fig. 2.2.1 may be used. The axes of these test specimens are to be located at approximately one quarter of the thickness from one of the rolled surfaces.



a = thickness of material

Fig. 2.2.3
Test specimen dimensions for plates, strip and sections – I

2.1.7 As an alternative to 2.1.6, test specimens with a width of other than 25 mm may be used subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. A ratio of width/thickness of 8:1 should not be exceeded.

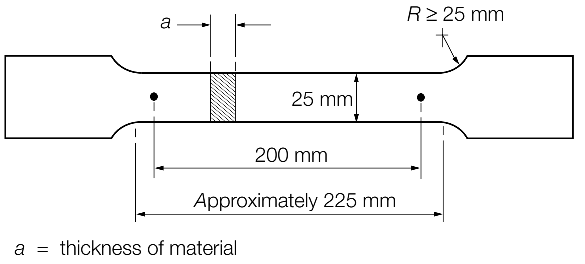


Fig. 2.2.4
Test specimen dimensions for plates, strip and sections – II

2.1.8 For pipes and tubes, the test specimens may consist of a suitable length tested in full cross-section with the ends plugged. The gauge length is to be $5,65\sqrt{S_o}$ or 50 mm, and the length of the test specimen between the grips or plugs, whichever is the smaller, is to be not less than the gauge length plus D, where D is the external diameter. Alternatively, test specimens may be prepared from strips cut longitudinally and machined to the dimensions shown in Fig. 2.2.5 or Fig. 2.2.6. The parallel test length is not to be flattened, but the enlarged ends may be flattened for gripping in the testing machine. The cross-sectional area of this type of test specimen is to be calculated from:

$S_o = ab$

where

S_o = cross-sectional area
a = average radial thickness
b = average width

Test specimens of circular cross-section may also be used provided that the wall thickness is sufficient to allow the machining of such specimens to the dimensions shown in Fig. 2.2.1, with their axes located at the mid-wall thickness.

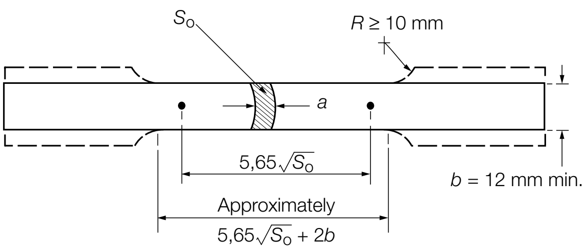


Fig. 2.2.5
Test specimen dimensions for pipes and tubes – I

2.1.9 For wire, the test specimen may consist of a suitable length tested in full cross-section. The gauge length is to be 200 mm and the parallel test length 250 mm.

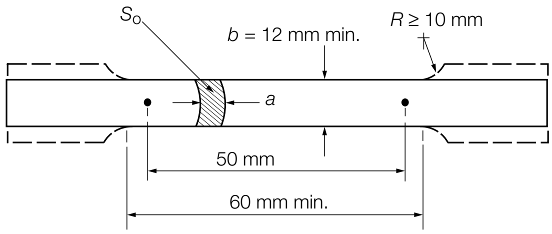


Fig. 2.2.6
Test specimen dimensions for pipes and tubes – II

2.1.10 For grey iron castings, the test specimens are to be machined to the dimensions shown in Fig. 2.2.7 or Fig. 2.2.8.

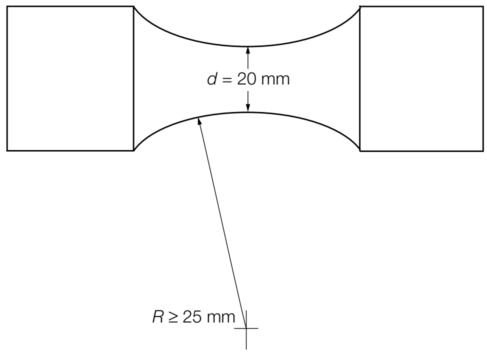


Fig. 2.2.7
Test specimen dimensions for grey iron castings – I

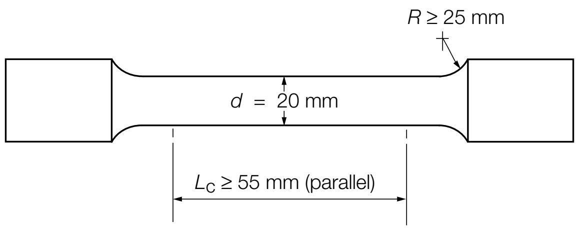


Fig. 2.2.8
Test specimen dimensions for grey iron castings – II

2.1.11 The dimensions of test specimens from weldments and the procedures for testing them are given in Ch 11,2.

2.1.12 Through-thickness tensile test specimens may be, at the option of the steelmaker, either plain test specimens, Fig. 2.2.9, or test specimens with welded extensions, Fig. 2.2.10. For both types of test specimens the diameter of the parallel portion is to be not less than:

6 mm where plate thickness ≤ 25 mm
10 mm where plate thickness > 25 mm

The extension pieces are to be of steel with a tensile strength exceeding that of the plate to be tested and may be attached to the plate surfaces by manual, resistance or friction welding carried out in such a way as to ensure a minimal heat affected zone.

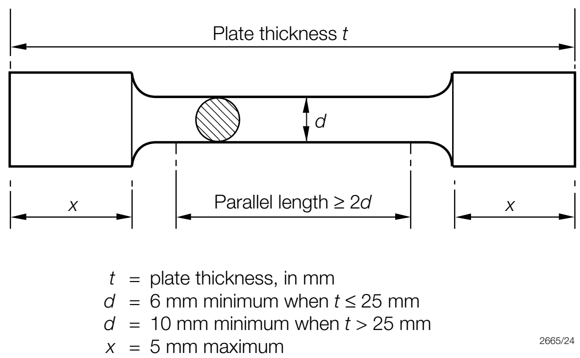


Fig. 2.2.9 Plain test specimen

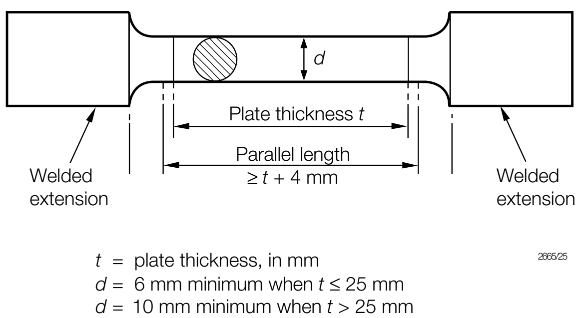


Fig. 2.2.10 Test specimen with welded extension

2.1.13 Tolerances on tensile specimen dimensions are to be in accordance with ISO 6892-84 and ISO 185-88 as appropriate.

2.2 Definition of yield stress for steel

2.2.1 The yield phenomenon is not exhibited by all the steels detailed in these Rules but, except for austenitic and duplex stainless steels, the term 'yield stress' is used throughout when requirements are specified for acceptance testing at ambient temperature. For the purposes of the Rules, the terms 'yield stress' and 'yield strength' are to be regarded as synonymous.

2.2.2 Where reference is made to 'yield stress' in the requirements for carbon, carbon-manganese and alloy steel products and in the requirements for the approval of welding consumables, either the upper yield stress or, where this is not clearly exhibited, the 0,2 per cent proof stress or the 0,5 per cent proof stress under load is to be determined. In cases of dispute, the 0,2 per cent proof stress is to be determined.

2.2.3 For austenitic and duplex stainless steel products and welding consumables, both the 0,2 and the 1,0 per cent proof stresses are to be determined.

2.3 Procedure for testing at ambient temperature

2.3.1 Except as provided in 2.3.5, the elastic stress rate is not to exceed 30 N/mm^2 per second for the determination of the upper yield or proof stress of steels and is not to exceed 10 N/mm^2 per second in measuring the proof stress of other materials. After reaching the yield or proof load, the straining rate may be increased to a maximum of 40 per cent of the gauge length per minute for the determination of the tensile strength.

2.3.2 For steel, the upper yield stress is to be calculated from:

(a) the load immediately prior to a distinct drop in the testing machine lever; or
(b) the load immediately prior to a fall back in the movement of the pointer or the load at a marked hesitation of this pointer; or
(c) a load/extension diagram using the value of load measured either at the commencement of plastic deformation at yield or at the first peak obtained during yielding even when that peak is equal to or less than any subsequent peaks observed.

2.3.3 When a well defined yield point cannot be obtained, the 0,5 or 1,0 per cent proof stress under load is to be calculated from the load corresponding to a total extension of 0,5 or 1,0 per cent of the original gauge length. This extension is to be measured either by the use of a suitable extensometer or by dividers.

2.3.4 The 0,2 or 1,0 per cent proof stress (non-proportional elongation) is to be determined from an accurate load/extension diagram by drawing a line parallel to the straight elastic portion and distant from it an amount representing 0,2 or 1,0 per cent of the extensometer gauge length. The point of intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2 or 1,0 per cent proof stress can be calculated.

2.3.5 For the determination of the tensile strength of flake graphite cast iron, the stress rate is not to exceed 10 N/mm^2 per second.

2.3.6 A measured elongation value is to be regarded as valid only if the fracture occurs within the gauge length and at least the following distances from the gauge marks:

Round test specimen: 1,25*d*
Flat test specimen: *a* plus width of specimen

The measurement is valid irrespective of the position of the fracture, if the percentage elongation after fracture reaches at least the specified value, and this is to be stated in the test report.

2.4 Equivalent elongations

2.4.1 When a gauge length other than $5,65\sqrt{S_o}$ is used, the equivalent percentage elongation value is to be calculated using the following formula:

$$A = \frac{A_R}{2}\left(\frac{L_o}{\sqrt{S_o}}\right)^{0,40}$$

where

A_R = actual measured percentage elongation of test specimen
S_o = actual cross-sectional area of test specimen
L_o = actual gauge length of test piece
A = equivalent percentage elongation for a test specimen with a gauge length of $5,65\sqrt{S_o}$

2.4.2 Alternatively, where a number of test specimens of similar material and dimensions are involved, the actual percentage elongation values may be recorded, provided that the equivalent specified minimum elongation value appropriate for the test specimen dimensions is calculated from the formula in 2.4.1 and is recorded on the test certificate.

2.4.3 For proportional test specimens having a gauge length other than $5,65\sqrt{S_o}$, the equivalent elongation may be calculated using the following factors (*d* is the diameter of the test specimen):

Actual gauge length	Factor for equivalent elongation on $5,65\sqrt{S_o}$
$4\sqrt{S_o}$	x 0,870
$8,16\sqrt{S_o}$	x 1,158
$11,3\sqrt{S_o}$	x 1,317
$4d$	x 0,916
$8d$	x 1,207

2.4.4 For non-proportional test specimens with gauge lengths of 50 mm and 200 mm, the equivalent elongation values tabulated in ISO 2566 are to apply.

2.4.5 The above conversions are reliable only for carbon, carbon-manganese and low alloy steels with a tensile strength not exceeding 700 N/mm^2 in the hot rolled, annealed, normalized, or normalized and tempered condition.

2.4.6 For alloy steels in the quenched and tempered condition, the following conversions may be used for proportional test specimens with a gauge length of $4\sqrt{S_o}$:

Actual percentage elongation on $4\sqrt{S_o}$	Equivalent elongation on $5,65\sqrt{S_o}$
22	17
20	15
18	13
17	12
16	12
15	11
14	10
12	8
10	7
8	5

2.4.7 Any proposals to use conversion factors for equivalent elongation values for the following materials are to be agreed with the Surveyors:

(a) Carbon, carbon-manganese and alloy steels in the normalized or normalized and tempered condition with a tensile strength exceeding 700 N/mm^2.
(b) Cold-worked steels.
(c) Austenitic stainless steels.
(d) Non-ferrous alloys.

2.5 Procedure for testing at elevated temperatures

2.5.1 The test specimens used for the determination of lower yield or 0,2 per cent proof stress at elevated temperatures are to have an extensometer gauge length of not less than 50 mm and a cross-sectional area of not less than 65 mm^2. Where, however, this is precluded by the dimensions of the product or by the test equipment available, the test specimen is to be of the largest practicable dimensions.

2.5.2 The heating apparatus is to be such that the temperature of the specimen during testing does not deviate from that specified by more than ±5°C.

2.5.3 The straining rate when approaching the lower yield or proof load is to be controlled within the range 0,1 to 0,3 per cent of the extensometer gauge length per minute.

2.5.4 The time intervals used for estimation of strain rate from measurements of strain are not to exceed 6 seconds.

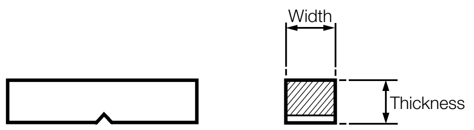
■ *Section 3*
Impact tests

3.1 Dimensions of test specimens

3.1.1 Impact tests are to be of the Charpy V-notch type. The test specimens are to be machined to the dimensions and tolerances given in Table 2.3.1 and are to be carefully checked for dimensional accuracy.

Table 2.3.1 Dimensions and tolerances for Charpy V-notch impact test specimens

Dimension	Nominal	Tolerance
Length, mm	55	±0,60
Width, mm– standard specimen	10	±0,11
– standard subsidiary specimen	7,5	±0,11
– standard subsidiary specimen	5	±0,06
Thickness, mm	10	±0,06
Angle of notch	45°	±2°
Depth below notch, mm	8	±0,06
Root radius, mm	0,25	±0,025
Distance of notch from end of test specimen, mm	27,5	±0,42
Angle between plane of symmetry of notch and longitudinal axis of test specimen	90°	±2°



3.1.2 For material under 10 mm in thickness, the largest possible size of standard subsidiary Charpy V-notch test specimen is to be prepared with the notch cut on the narrow face. Generally, impact tests are not required when the thickness of the material is less than 6 mm.

3.2 Testing procedures

3.2.1 All impact tests are to be carried out on Charpy machines approved by Lloyd's Register (hereinafter referred as LR) and, complying with the requirements of ISO 148 or other recognized International or National Standards and having a striking energy of not less than 150 J. The testing machines are to be calibrated annually using either a direct or indirect method.

3.2.2 Charpy V-notch impact tests may be carried out at ambient or lower temperatures in accordance with the specific requirements given in subsequent Chapters of these Rules. Where the test temperature is other than ambient, the temperature of the test specimen is to be controlled to within ±2°C for sufficient time to ensure uniformity throughout the cross-section of the test specimen, and suitable precautions are to be taken to prevent any significant change in temperature during the actual test. In cases of dispute, ambient temperature is to be considered as 18°C to 25°C.

3.2.3 Where standard subsidiary Charpy V-notch test specimens are necessary, the minimum energy values required are to be reduced as follows:

Specimen 10 x 7,5 mm: 5/6 of tabulated energy.
Specimen 10 x 5 mm: 2/3 of tabulated energy.

3.2.4 When reporting results, the specimen dimensions and the units used for expressing the energy absorbed (Joules) and the testing temperature are to be clearly stated.

■ *Section 4*
Ductility tests for pipes and tubes

4.1 Bend tests

4.1.1 The test specimens are to be cut as circumferential strips of full wall thickness and with a width of not less than 40 mm. For thick walled pipes, the thickness of the test specimens may be reduced to 20 mm by machining. The edges of the specimens may be rounded to a radius of 1,6 mm.

4.1.2 Testing is to be carried out at ambient temperature, and the specimens are to be doubled over a former whose diameter is to be in accordance with the specific requirements for the material. For submerged arc welded tube the test piece is to be bent with the root of the weld in tension. For other tubes, the test piece is to be bent in the original direction of curvature. In all cases, the welds are to be in the middle of the test specimen. The test is considered to be satisfactory if, after bending, the specimens are free from cracks and laminations. Small cracks at the edges of the test specimens are to be disregarded.

4.2 Flattening tests

4.2.1 Ring test specimens are to be cut with the ends perpendicular to the axis of the pipe or tube. The length of the specimen is to be equal to 1,5 times the external diameter of the pipe or tube, but is to be not less than 10 mm or greater than 100 mm. Alternatively, the length of the test specimen may be 40 mm irrespective of the external diameter.

4.2.2 Testing is to be carried out at ambient temperature and is to consist of flattening the specimens in a direction perpendicular to the longitudinal axis of the pipe. Flattening is to be carried out between two plain parallel and rigid platens which extend over both the full length and the width after flattening of the test specimen. Flattening is to be continued until the distance between the platens, measured under load, is not greater than the value given by the formula:

$$H = \frac{t\,(1 + C)}{C + \frac{t}{D}}$$

where
H = distance between plates, in mm
t = specified thickness of the pipe, in mm
D = specified outside diameter, in mm
C = a constant dependent on the steel type and detailed in the specific requirements

After flattening, the specimens are to be free from cracks or other flaws. Small cracks at the ends of the test specimens may be disregarded.

4.2.3 For welded pipes or tubes, the weld is to be placed at 90° to the direction of flattening.

4.3 Drift expanding tests

4.3.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The edges of the end to be tested may be rounded by filing.

4.3.2 For steel tubes, the length of the specimen is to be at least 1,5 times the external diameter of the tube except when a mandrel with an included angle of 30° is used, in which case the length of the specimen is to be twice the external diameter of the tube. In all cases the length is not to be less than 50 mm.

4.3.3 For copper and copper alloy tubes the length of the specimen is to be not less than twice and not more than three times the external diameter.

4.3.4 For aluminium and light alloy tubes the length of the specimen is to be at least twice the external diameter.

4.3.5 Testing is to be carried out at ambient temperature and is to consist of expanding the end of the tube symmetrically by means of a hardened conical steel mandrel having a total included angle of 30°, 45° or 60°, *see* Fig. 2.4.1. The mandrel is to be forced into the test specimen until the percentage increase in the outside diameter of the end of the test specimen is not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The mandrel is to be lubricated, but there is to be no rotation of the tube or mandrel during the test. The expanded portion of the tube is to be free from cracks or other flaws.

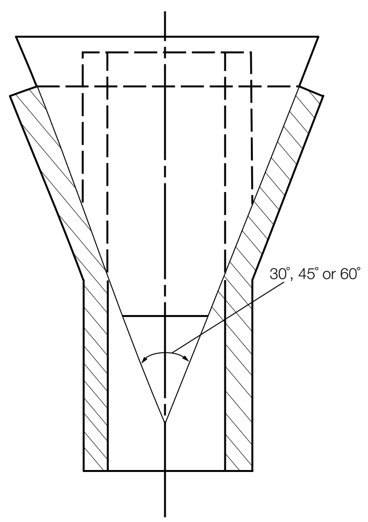


Fig. 2.4.1 Drift expanding test

4.4 Flanging tests

4.4.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The length of the specimens is to be at least equal to the external diameter of the tube and such that after testing the portion that remains cylindrical is not less than half the external diameter. The edges of the end to be tested may be rounded by filing.

4.4.2 Testing is to be carried out at ambient temperature and is to consist of flanging the end of the tube symmetrically by means of hardened conical steel mandrels.

4.4.3 The first stage of flanging is to be carried out with a conical angled mandrel having an included angle of approximately 90°, *see* Fig. 2.4.2(a). The completion of the test is achieved with a second forming tool as shown in Fig. 2.4.2(b). The mandrels are to be lubricated and there is to be no rotation of the tube or mandrels during the test. The test is to continue until the drifted portion has formed a flange perpendicular to the axis of the test specimens. The percentage increase in the external diameter of the end of the specimens is to be not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The cylindrical and flanged portion of the tube is to be free from cracks or other flaws.

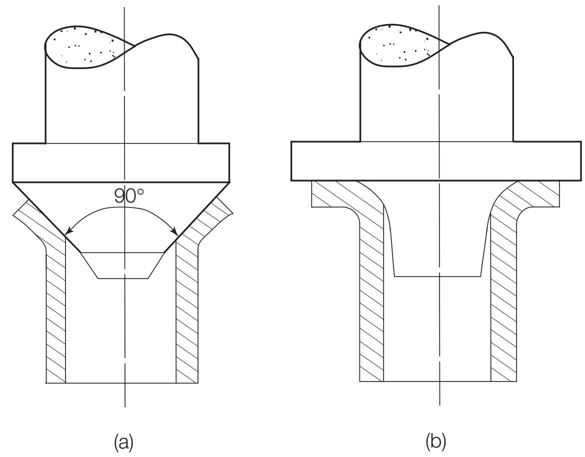


Fig. 2.4.2 Flanging test

■ *Section 5* **Embrittlement tests**

5.1 Temper embrittlement tests

5.1.1 The test material is to be heat treated in accordance with the specification except that after tempering:
(a) half the material is to be water quenched;
(b) the other half is to be cooled from the tempering temperature to 300°C at a rate not exceeding 10°C per minute.

5.1.2 Impact tests in accordance with Section 3 are to be made on the material in each condition at temperatures over a range wide enough to establish the upper and lower shelf energies and temperatures, tests being made at no less than three intermediate temperatures.

5.1.3 A set of three specimens is to be tested at each temperature. The results are to be plotted separately for each condition, in the form illustrated in Fig. 2.5.1. In addition, the test temperatures, proportions of crystallinity and absorbed energies for all the specimens tested are to be reported.

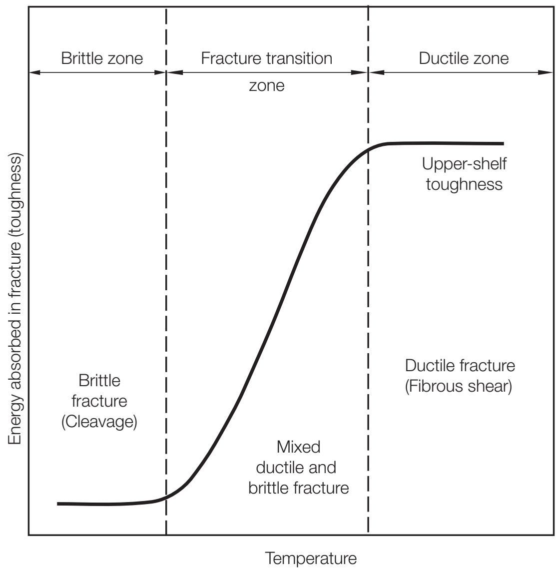


Fig. 2.5.1 Idealised transition curve

5.1.4 The transition temperature for each condition is to be taken as the mid-temperature of the fracture transition zone. The difference between the two transition temperatures is to be reported.

5.2 Strain age embrittlement tests

5.2.1 The test material is to be heat treated in accordance with the specification and then subjected to five per cent strain. Half of the test material is then to be heated to 250°C and held for one hour.

5.2.2 Impact tests in accordance with 5.1.2 are to be made in both the strained and unstrained conditions.

5.2.3 The tests are to comply with 5.1.3.

5.2.4 The test results are treated in accordance with 5.1.4.

5.3 Hydrogen embrittlement tests

5.3.1 Two specimens are to be tested. The specimens are to be of a diameter of 20 mm. Where this is not practicable a diameter of 14 mm may be accepted.

5.3.2 One specimen is to be tested within a maximum of 3 hours after machining. Where the specimen diameter is 14 mm, the time limit is 1,5 hours. Alternatively, the specimen may be cooled to –60°C immediately after machining and kept at that temperature for a maximum period of 5 days before being tested.

5.3.3 The other specimen is to be tested after baking at 250°C for 4 hours. Where the specimen diameter is 14 mm the baking time is to be 2 hours.

5.3.4 A strain rate not exceeding $0{,}0003s^{-1}$ is to be used during the entire test, until fracture occurs.

5.3.5 Tensile strength, elongation and reduction of area are to be reported.

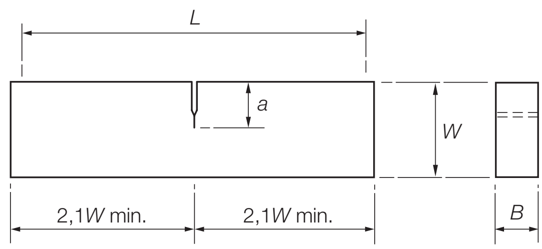
5.3.6 The ratio Z_1/Z_2 is to be reported, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

■ *Section 6* **Crack tip opening displacement tests**

6.1 Dimensions of test specimens

6.1.1 Unless agreed otherwise, tests are to be made on specimens of the full section thickness and which conform to a nationally agreed standard.

6.1.2 Normally the specimens are to be rectangular with the main dimensions as indicated in Fig. 2.6.1 and are to be tested in three point bending.

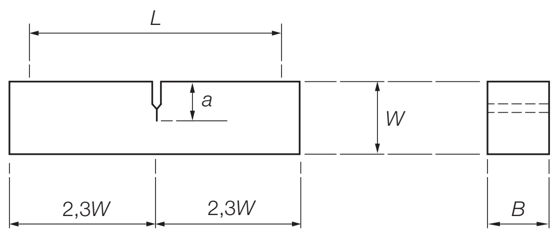


B = thickness
W = width = 2*B*
a = effective crack length = 0,45*W* to 0,55*W*
L = loading span = 4*W*

Fig. 2.6.1
Outline dimensions of the preferred specimen

6.1.3 A subsidiary specimen as in Fig. 2.6.2 may be used by agreement.

6.1.4 In each case the notch is to be positioned at the centre of the loading span; its root radius is not to exceed 0,10 mm. The notch is to be extended by the generation of a fatigue crack to give an effective crack length of the dimension *a*. For this purpose, the fatigue stress ratio, R_1, is to be within the range 0 to 0,1 and the fatigue intensity is not to exceed $0{,}63\sigma_\gamma B^{1/2}$ where σ_γ is the 0,2 per cent proof stress at the test temperature.



B = thickness
W = width = *B*
a = effective crack length (to be agreed between the purchaser and manufacturer)
L = loading span = 4*W*

Fig. 2.6.2
Outline dimensions of the subsidiary specimen

6.2 Test equipment

6.2.1 Whenever possible, tests are to be made using machines operating under displacement control. The type of control is to be recorded.

6.2.2 The test equipment is to be calibrated annually.

6.2.3 The crack opening displacement gauge is to have an accuracy of at least one per cent. It is to be calibrated at least once every day of testing and at intervals of no more than 10 tests. It should be demonstrated that the calibration is satisfactory for the test conditions.

6.3 Testing procedures

6.3.1 Tests are to be made in a recognized test house in accordance with a nationally accepted standard.

6.3.2 Unless otherwise agreed, all tests on unwelded wrought material are to be made on specimens taken transverse to the principal working direction and are to be through-thickness notched.

6.3.3 Where tests are made on weld material, the fatigue crack should be arranged to sample the maximum amount of unrefined weld metal.

6.3.4 Where tests are made on the Heat Affected Zone (H.A.Z.) of a weld, a K or single bevel weld preparation is recommended. The region of lowest fracture toughness in the Heat Affected Zone should be identified for the particular steel and weld procedure by means of preliminary tests. The fatigue crack is to be accurately positioned to sample as high a proportion of this critical region as possible and after testing has been completed, the specimen is to be sectioned to check that this has been achieved. Sufficient tests should be made to ensure that the critical region has been sampled in at least three specimens.

6.3.5 At least three valid tests are to be made for each material condition. Invalid tests are to be disregarded and the tests repeated.

6.3.6 Local pre-compression of the test specimen ahead of the notch is acceptable in order to provide an acceptably even fatigue crack front.

6.3.7 The temperature of the test piece is to be measured to within ±2°C over the range minus 196°C to +200°C and to within ±5°C outside this range. The temperature should be measured at a point on the specimen not farther than 2 mm away from the crack tip.

6.4 Validity requirements

6.4.1 The test is to be regarded as invalid if:
(a) the fatigue crack front is not in a single plane;
(b) any part of the fatigue crack surface lies in a plane whose angle with the plane of the notch exceeds 10°;
(c) the length of any part of the fatigue crack is less than 0,025*W* or 1,25 mm, whichever is the greater;
(d) the difference between the maximum and minimum lengths of the fatigue crack exceeds 0,1*W*;
(e) the difference between any two of the lengths of the fatigue crack at 0,25*B*, 0,5*B* and 0,75*B* exceeds 0,05*W*.

6.4.2 In addition, for tests on welds and Heat Affected Zones (H.A.Z.), the following criteria are to be complied with:
(a) Weld metal. The fatigue crack front shall not extend outside the weld metal deposit and 80 per cent should be within 2 mm of the fusion line.
(b) Grain coarsened H.A.Z.. The fatigue crack should be within 0,5 mm of the fusion line and should sample all of the grain coarsened H.A.Z. present. However, if fusion line irregularities prevent this, a sample including as much grain coarsened H.A.Z. as possible may be accepted.
(c) Subcritical/intercritical H.A.Z. boundary. The fatigue crack is to sample the boundary between the subcritical and intercritical regions of the H.A.Z. However, if fusion line irregularities prevent this, a sample including as much relevant microstructure as possible may be accepted.

6.5 Test reports

6.5.1 The test report is to include:
(a) details of the material, its condition and size;
(b) the thickness and width of the test specimen;
(c) the fatigue pre-cracking conditions;
(d) the test temperature and environment;
(e) the test machine control system and rate of change of displacement or load;
(f) crack length measurements;
(g) force/displacement records, preferably in the form of an autographic record;
(h) the critical crack opening displacement;
(j) a photograph of the fracture;
(k) any observation on the fracture surface.

■ *Section 7* Bend tests

7.1 Application and testing

7.1.1 Bend tests are mainly used in the testing of welds. The requirements are given in Ch 11,2.

■ *Section 8* Corrosion tests

8.1 Intergranular corrosion test

8.1.1 For all products other than pipes, the material for the test specimens is to be taken adjacent to that for the tensile test and is to be machined to suitable dimensions for either a round or rectangular section bend test. The diameter or thickness is to be not more than 12 mm, and the total surface area is to be between 1500 mm^2 and 3500 mm^2.

8.1.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases the total surface area is to be between 1500 mm^2 and 3500 mm^2.

8.1.3 Specimens are to be heated to a temperature of 700 ± 10ºC for 30 minutes, followed by rapid cooling in water. They are then to be placed on a bed of copper turnings (50 g per litre of test solution) and immersed for 15 to 24 hours in a boiling solution of the following composition:

- 100 g of hydrated copper sulphate granules ($CuSO_4 . 5H_2O$)
- 184 g (100 ml) sulphuric acid (density 1,84 g/ml) added dropwise to distilled water to make 1 litre of solution.

Precautions are to be taken during boiling to prevent concentration of the solution by evaporation.

8.1.4 After immersion, the full cross-section test specimens from pipes are to be subjected to a flattening test in accordance with Ch 2,4.2. All other test specimens are to be bent, at ambient temperature, through 90º over a former with a diameter equal to twice the diameter or thickness of the test specimen.

8.1.5 After flattening or bending, the test specimens are to be free from cracks on the outer, convex surface.

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for hot rolled plates and sections intended for use in the construction of ships, other marine structures, machinery, boilers and pressure vessels. These requirements are also applicable to hot rolled bars, except where such materials are intended for the manufacture of bolts, plain shafts, etc., by machining operations only. Where used for this purpose hot rolled bars are to comply with the requirements of Chapter 5.

1.1.2 These items are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2 to 10.

1.1.3 As an alternative to 1.1.2, materials which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or are approved for a specific application. Particular attention is to be taken of the minimum required under thickness tolerance, *see* 1.6. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Strip material which is hot coiled after rolling and subsequently uncoiled, cold flattened and cut to the required dimensions is to be subject to the appropriate requirements of this Chapter.

1.2 Steel with guaranteed through thickness properties – 'Z' grade steel

1.2.1 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, 'Z' grade steel. These strains are usually associated with thermal contraction and restraint during welding, particularly for full penetration 'T'-butt welds, but may also be associated with loads applied in service or during construction. Where these strains are of sufficient magnitude, lamellar tearing may occur. Requirements for 'Z' grade plate material are detailed in Section 8. It is the responsibility of the fabricator to make provision for the use of this material.

1.2.2 Steels intended to have guaranteed through thickness properties will include the supplementary suffix Z25 or Z35 in the designation, for example: LR DH36 Z35.

1.3 Manufacture

1.3.1 All materials are to be manufactured at works which have been approved by LR for the type and grade of steel which is being supplied and for the relevant steelmaking and processing route.

1.3.2 Steel is to be cast in metal ingot moulds or by the continuous casting process. The size of the ingot, billet or slab is to be proportional to the dimensions of the final product such that the reduction ratio is normally to be at least 3 to 1. Sufficient discard is to be taken to ensure soundness in the portion used for further processing.

1.3.3 The cast analysis to be used for certification purposes is to be determined after all alloying additions have been carried out and sufficient time allowed for such an addition to homogenize.

1.3.4 Material may be supplied either as-rolled, normalized, normalizing rolled, or thermomechanically controlled rolled. The following definitions apply:

(a) As-rolled (AR) refers to products that are supplied without any heat treatment after completion of the rolling operations. The rolling temperature and reduction may not be strictly controlled resulting in a variable grain size.

(b) Normalizing (N) is a separate austenitizing heat treatment after rolling which refines the grain size, improving the mechanical properties.

(c) Normalizing rolling (NR) is a procedure in which the final deformation is carried out in the normalizing temperature range resulting in a material condition equivalent to that obtained by normalizing. Normalizing rolling may, therefore, be acceptable as a direct equivalent of a normalizing heat treatment.

(d) Thermomechanically controlled rolling (TM) is a procedure in which both the temperatures and thickness reductions are strictly controlled and in which rolling is completed at a specified temperature close to, and may be less than, that at which ferrite formation is complete. This results in a microstructure and mechanical properties which cannot be obtained by a normalizing heat treatment.

(e) Quenching and Tempering (QT) involves quenching, a heat treatment process in which steel is heated to an appropriate temperature above the A_{c3} and then cooled with an appropriate coolant for the purpose of hardening the microstructure, followed by tempering, a process in which the steel is re-heated to an appropriate temperature, not higher than the A_{c1} to restore the toughness properties by improving the microstructure.

1.3.5 Where material is being produced by a normalizing rolling or a thermomechanically controlled process (T.M.) an additional program of tests for approval is to be carried out under the supervision of the Surveyors and the results are to be to the satisfaction of Lloyd's Register (hereinafter referred to as 'LR').

1.3.6 The mechanical properties may be improved by means of accelerated cooling which involves controlled cooling, at rates higher than are obtained by air cooling, after the final rolling operation. Materials may be supplied in this condition subject to approval by LR. Accelerated cooling does not include quenching and the mechanical properties conferred by it cannot be reproduced by subsequent normalizing or other heat treatment.

1.3.7 Weldable high strength steels may be supplied in the quenched and tempered condition for other marine structures, *see* Section 10.

1.4 Quality of materials

1.4.1 Surface and internal imperfections not prejudicial to the proper application of the steel are not, except by special agreement, to be grounds for rejection. Where necessary, suitable methods of non-destructive examination may be used for the detection of harmful surface and internal defects. The extent of this examination, together with an appropriate acceptance standard, is to be agreed between the purchaser, steelmaker and Surveyor and is to be included in the manufacturing specification.

1.5 Dimensional tolerances

1.5.1 For materials intended for hull structural purposes as detailed in Sections 2, 3 and 10, the under thickness tolerance of plates, strip and wide flats is not to exceed 0,3 mm.

1.5.2 The minus tolerance on sections (except for wide flats) is to be in accordance with the requirements of a recognized National or International Standard.

1.5.3 The attention of Shipbuilders and Owners is to be drawn to the fact that when thickness gauging is carried out during the ship's life, estimation of the diminution of hull plating and structure will be based on the nominal thickness, this being the original approved thickness for the item of structure under consideration.

1.5.4 The under thickness tolerance acceptable for classification is to be considered as the lower limit of a range of thickness tolerance which could be found in the normal production of a conventional rolling mill manufacturing material, on average, to the nominal thickness.

1.5.5 The Shipbuilder and Owner may agree in individual cases whether they wish to specify a more stringent under thickness tolerance than that given in 1.5.1.

1.5.6 The minus tolerances for plates and wide flats intended for machinery structures are given in Section 5.

1.5.7 For materials intended for applications as detailed in Sections 4 and 6, no minus tolerance is permitted in the thickness of plates and strip. The minus tolerances on sections are to comply with the requirements of a recognized National or International Standard.

1.5.8 For the materials detailed in Section 7, the under thickness tolerance of material intended for use in the construction of cargo tanks is not to exceed 0,3 mm. For other applications, no minus tolerance is permitted in the thickness of plates and strip.

1.5.9 Dimensional tolerances for material detailed in Section 9 are given in Table 3.9.3.

1.5.10 The thickness of plates and strip is to be measured at random locations whose distance from a longitudinal edge is to be at least 10 mm. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a recognized National or International Standard.

1.5.11 Tolerances relating to length, width, flatness and over thickness are to comply with a National or International Standard.

1.5.12 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

1.6 Heat treatment

1.6.1 Acceptable conditions of supply are specified in subsequent Sections of this Chapter.

1.6.2 The manufacturer is to carry out any heat treatment which may be necessary to prevent hydrogen cracking or to make the material in a safe condition for transit. The Surveyor is to be advised of any heat treatment proposed.

1.6.3 Where material is manufactured using a thermo-mechanically controlled process consideration must be given to the possibility of consequent reduction in mechanical properties if it is subjected to heating for forming or stress relieving or is welded using a high heat input.

1.7 Test material and mechanical tests

1.7.1 Depending on the type of product, provision is made in subsequent Sections of this Chapter for the testing of individual items or for batch testing. Where the latter is permitted, all materials in a batch presented for acceptance tests are to be of the same product form, (e.g. plates, flats, sections, etc.), from the same cast and in the same condition of supply.

1.7.2 The test samples are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed. The test specimens are not to be separately heat treated in any way.

1.7.3 The test material is to be taken from the thickest piece in each batch.

1.7.4 Test material is to be taken from the following positions:

(a) At the square cut end of plates and flats greater than 600 mm wide, approximately one-quarter width from an edge, *see* Fig. 3.1.1(a).
(b) For flats 600 mm or less in width, bulb flats and other solid sections, at approximately one-third of the width from an edge, *see* Fig. 3.1.1(b), (c) and (d). Alternatively, in the case of channels, beams or bulb angles, at approximately one-quarter of the width from the centreline of the web, *see* Fig. 3.1.1(c).
(c) For rectangular hollow sections, at approximately the centre of any side, *see* Fig. 3.1.1(e). For circular hollow sections, at any position on the periphery.
(d) For bars intended for purposes as detailed in Sections 2, 3, 5 and 9, at approximately one-third of the radius or half-diagonal from the outer surface, *see* Fig. 3.1.1(f). For smaller bars, the position of the test material is to be as close as is possible to the above.
(e) For bars intended for the applications detailed in Sections 4, 6 and 7 at approximately 12,5 mm below the surface. For bars up to 25 mm diameter, the test specimens may be machined coaxially.
(f) For plates and flats with thicknesses in excess of 40 mm, full thickness specimens may be prepared, but when instead a machined round specimen is used then the axis is to be located at a position lying one-quarter of the product thickness from the surface as shown in Fig. 3.1.1(g).

1.7.5 Tensile test specimens and impact test specimens, where required for the type and grade of product being supplied, are to be prepared from each item or batch of material submitted for acceptance.

1.7.6 Where the finished width of plates and flats is greater than 600 mm, the tensile test specimens are to be cut with their principal axes perpendicular to the final direction of rolling. For all other rolled products, the principal axes are to be parallel to the final direction of rolling.

1.7.7 The tensile test specimens are to be machined to the dimensions detailed in Ch 2,2.1.6 and 2.1.7.

1.7.8 Impact test specimens are to be cut with their principal axes either parallel (longitudinal test) or perpendicular (transverse test) to the final direction of rolling, as required by subsequent Sections of this Chapter. Where both longitudinal and transverse impact properties are shown for a particular grade, only the longitudinal test is required to be carried out, unless otherwise specified by the purchase order or subsequent Sections of this Chapter. However, for plates and wide flats, by certifying that the product meets the requirements of the Rules, the manufacturer guarantees that the acceptance values will be met if tested in the transverse direction. The Surveyor may request testing in this direction to confirm conformity.

1.7.9 Impact test specimens are to be of the Charpy V-notch type, machined to the dimensions detailed in Chapter 2. They are to be taken from a position within 2 mm of one of the rolled surfaces, except that for plates and sections over 40 mm thick, the axes of the test specimens are to be at one-quarter of the thickness from one of the rolled surfaces. For bars and other similar products the axes of the test specimens are to be as specified in 1.7.4(d).

1.7.10 Standard test specimens 10 mm square are to be used, except where the thickness of the material does not allow this size of test specimen to be prepared. In such cases the largest possible size of subsidiary test specimen, in accordance with Table 2.3.1 is to be prepared, with the notch cut on the narrow face. Alternatively, for material of suitable thickness, the rolled surfaces may be retained so that the test specimen width will be the full thickness of the material. In such cases the tolerances for width given in Table 2.3.1 in Chapter 2 are not applicable. The notch is to be cut in a face of the test specimen which was originally perpendicular to the rolled surface. The position of the notch is to be not nearer than 25 mm to a flame-cut or sheared edge.

1.7.11 Impact tests are not required when the nominal material thickness is less than 6 mm.

1.7.12 The test procedures used for all tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.8 Visual and non-destructive examination

1.8.1 Surface inspection and verification of dimensions are the responsibility of the steelmaker and are to be carried out on all material prior to despatch. Acceptance by the Surveyors of material later found to be defective shall not absolve the steelmaker from this responsibility.

1.8.2 With the exception of 'Z' grade plate material (*see* Section 8) and bars for offshore mooring cable (*see* Section 9), the non-destructive examination of materials is not required for acceptance purposes, *see also* 1.4.1. However, manufacturers are expected to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

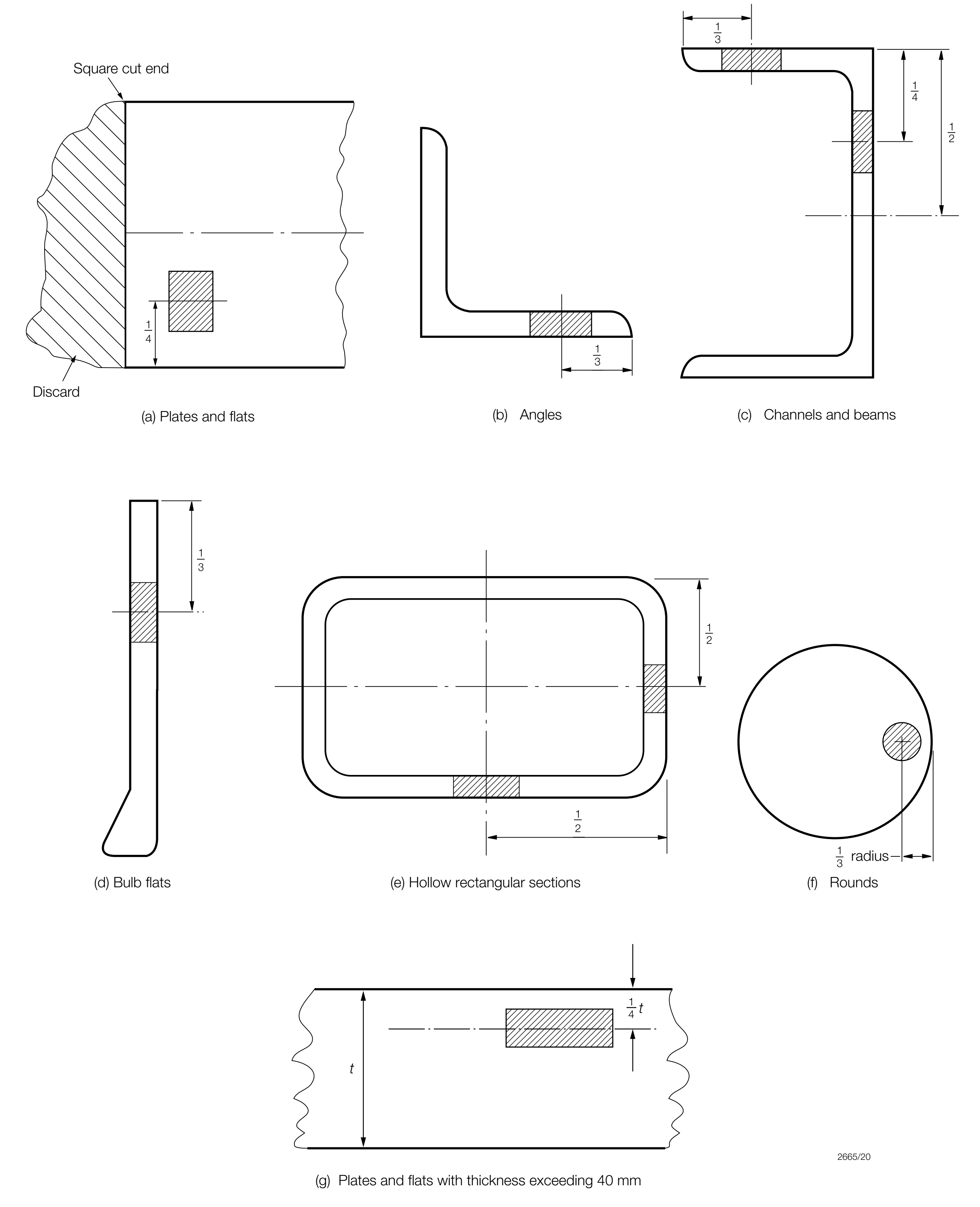


Fig. 3.1.1 Position of test material

1.9 Rectification of defects

1.9.1 For materials intended for structural purposes as detailed in Sections 2, 3 and 5, surface defects may be removed by local grinding provided that:

(a) the thickness is in no place reduced to less than 93 per cent of the nominal thickness, but in no case by more than 3 mm,

(b) each single ground area does not exceed 0,25 m^2,

(c) the total area of local grinding does not exceed two per cent of the total surface,

(d) the ground areas have smooth transitions to the surrounding surface.

Where necessary, the entire surface may be ground to a maximum depth as given by the underthickness tolerances of the product. The extent of such rectification is to be agreed in each case with the Surveyors and is to be carried out under their supervision, unless otherwise agreed. They may request that complete removal of the defect is proven by suitable non-destructive examination of the affected area.

1.9.2 Surface defects which cannot be dealt with as in 1.9.1 may be repaired by chipping or grinding followed by welding, subject to the Surveyor's consent and under his supervision, provided that:

(a) after removal of the defect and before welding, the thickness of the item is in no place reduced by more than 20 per cent,

(b) each single weld does not exceed 0,125 m^2,

(c) the total area of welding does not exceed two per cent of the surface of the side involved,

(d) the distance between any two welds is not less than their average width,

(e) the welds are of reasonable size and made with an excess layer of beads which is then ground smooth to the surface level,

(f) elimination of the defect is proven by suitable non-destructive examination of the affected area,

(g) welding is carried out by an approved procedure and by competent operators using approved electrodes and the repaired area is ground smooth to the correct nominal thickness,

(h) when requested by the Surveyor, the item is normalized or otherwise suitably heat treated after welding and grinding, and

(j) at the discretion of the Surveyor, the repaired area is proven free from defects by suitable non-destructive examination.

1.9.3 For materials intended for applications as detailed in Sections 4, 6 and 7, surface defects may be removed by grinding in accordance with 1.9.1, except that when the thickness is reduced below that given in the approved plans, acceptance will be subject to special consideration. Weld repairs may also be carried out generally in accordance with 1.9.2, except that in all cases suitable heat treatment after welding and non-destructive testing of the repaired areas is required. The fabricator is to be advised regarding the position and extent of all repairs.

1.9.4 For plates which have been produced by a T.M. process or by normalizing rolling, repair by welding will be approved by the Surveyor only after procedure tests have shown that the mechanical properties have not been impaired.

1.9.5 Cracks, shells, sand patches and sharp edged seams are always considered defects which would impair the end use of the product and which require rejection or repair irrespective of their size and number. The same applies to other imperfections exceeding the acceptable limits.

1.10 Identification of materials

1.10.1 Every finished item is to be clearly marked by the manufacturer in at least one place with LR's brand ℛ and the following particulars:

(a) The manufacturer's name or trade mark.

(b) The grade of steel. The designations given in subsequent Sections of this Chapter may be preceded by the letters 'LR' in order to fully describe the grade, e.g. LR A, LR 490FG. LR LT-FH40, LR 316L, etc.

(c) When the material complies with the requirements of Section 8, the grade is to include the suffix Z25 or Z35, e.g. LR AH36 Z35.

(d) Identification number and/or initials which will enable the full history of the item to be traced.

(e) If required by the purchaser, his order number or other identification mark.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognizable.

1.10.2 Where a number of light materials are securely fastened together in bundles, the manufacturer may brand only the top piece of each bundle or, alternatively, a firmly fastened durable label containing the identification may be attached to each bundle.

1.10.3 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be unmistakably defaced, *see also* Ch 1,4.9.

1.11 Certification of materials

1.11.1 Each test certificate or shipping statement is to include the following particulars:

(a) Purchaser's name and order number.

(b) If known, the contract number for which the material is intended.

(c) Address to which material is dispatched.

(d) Name of steelworks.

(e) Description and dimensions of the material.

(f) Specification or grade of the steel.

(g) Identification number of piece, including test specimen number where appropriate.

(h) Cast number and chemical composition of ladle samples.

(j) Mechanical test results (not required on shipping statements).

(k) Condition of supply.

1.11.2 Before the test certificates or shipping statements are signed by the Surveyor, the steelmaker is required to provide a written declaration stating that the material has been made by an approved process, and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor, or an authorized deputy. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the steelworks and signed by an authorized representative of the manufacturer:

> 'We hereby certify that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register'.

1.11.3 When steel is not produced at the works at which it is rolled, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the chemical composition of ladle samples. The works at which the steel was produced must be approved by LR.

1.11.4 The form of certificates produced by computer systems is to be agreed with the Surveyor.

■ *Section 2* Normal strength steels for ship and other structural applications

2.1 Scope

2.1.1 The requirements of this Section are primarily intended to apply to steel plates and wide flats not exceeding 100 mm in thickness and sections and bars not exceeding 50 mm in thickness in Grades A, B, D and E. For greater thicknesses, variations in the requirements may be permitted or required for particular applications.

2.1.2 Additional approval tests may be required to verify the suitability for forming and welding of Grade E plate exceeding 50 mm in thickness.

2.2 Manufacture and chemical composition

2.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 3.2.1.

2.2.2 Small variations from the chemical compositions given in Table 3.2.1 may be allowed for Grade E steel in thicknesses exceeding 50 mm or when any Grade of steel is supplied in a thermo-mechanically controlled processed condition, provided that these variations are documented and approved in advance.

Table 3.2.1 Chemical composition and deoxidation practice

Grade	A	B	D	E
Deoxidation	For $t \leq 50$ mm: Any method (for rimmed steel, *see* Note 1)	For $t \leq 50$ mm: Any method except rimmed steel	For $t \leq 25$ mm: Killed	Killed and fine grain treated with aluminium
	For $t > 50$ mm: Killed	For $t > 50$ mm: Killed	For $t > 25$ mm: Killed and fine grain treated with aluminium	
Chemical composition % (*see* Note 5)				
Carbon	0,21 max. (*see* Note 2)	0,21 max.	0,21 max.	0,18 max.
Manganese	2,5 x C% min.	0,80 min. (*see* Note 3)	0,60 min.	0,70 min.
Silicon	0,50 max.	0,35 max.	0,10 – 0,35	0,10 – 0,35
Sulphur	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Phosphorus	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Aluminium (acid soluble)	—	—	0,015 min. (*see* Note 4)	0,015 min. (*see* Note 4)
	Carbon + $^1/_6$ of the manganese content is not to exceed 0,40%			

NOTES
1. For Grade A, rimmed steel may only be accepted for sections up to a maximum thickness of 12,5 mm, provided that it is stated on the test certificates or shipping statements to be rimmed steel.
2. The maximum carbon content for Grade A steel may be increased to 0,23% for sections.
3. Where Grade B is impact tested the minimum manganese content may be reduced to 0,60%.
4. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
5. Where additions of any other elements are made as part of the steelmaking practice, the content is to be recorded.

2.2.3 The manufacturer's declared analysis will be accepted subject to occasional checks if required by the Surveyors.

2.3 Condition of supply

2.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.2.2. Where alternative conditions are permitted these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material, but a steelmaker is to supply materials only in those conditions for which he has been approved by LR.

Table 3.2.2 Condition of supply

Grade	Thickness mm	Conditions of supply			
A and B	≤50	Any			(*see* Note 1)
	>50 ≤100	N	NR	TM	(*see* Note 2)
D	≤35	Any			(*see* Note 1)
	>35 ≤100	N	NR	TM	(*see* Note 3)
E	≤100	N		TM	(*see* Note 4)

N = normalized
NR = normalizing rolled
TM = thermomechanically controlled-rolled

NOTES
1. 'Any' includes as-rolled, normalized, normalizing rolled and thermomechanically controlled-rolled.
2. Plates, wide flats, sections and bars may be supplied in the as-rolled condition, subject to special approval from LR.
3. Sections in Grade D steel may be supplied in thicknesses greater than 35 mm in the as-rolled condition provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Sections in Grade E steel may be supplied in the as-rolled and normalizing rolled conditions provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.

2.3.2 Where normalizing rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

2.3.3 If a steel product supplied in the T.M. condition is to be subjected to heating for forming or stress relieving or is to be welded by a high energy input process, consideration must be given to the possibility of a consequent reduction in mechanical properties.

2.4 Mechanical tests

2.4.1 With the exception given in 2.4.2, one tensile test is to be made for each batch presented unless the weight of finished material is greater than 50 tonnes, in which case one test is to be made from a different piece from each 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast. For sections, the thickness to be considered is the thickness of the product at the point at which samples are taken for mechanical tests. A piece is to be regarded as the rolled product from a single slab or billet, or from a single ingot if this is rolled directly into plates, strip, sections or bars.

2.4.2 For plates of thickness exceeding 50 mm in Grade E steel, one tensile test is to be made on each piece.

2.4.3 For Grade A steel, Charpy V-notch impact tests are not required for routine acceptance test purposes when the thickness does not exceed 50 mm, or up to 100 mm thick if the material is supplied in either the normalized or thermo-mechanically controlled-rolled condition and has been fine grain treated. However, the manufacturer should confirm, by way of regular in-house checks, that the material will meet a requirement of 27 J at +20°C. The results of these checks shall be reported to the Surveyor. The frequency of these checks should as a minimum be every 250 tonnes.

2.4.4 When Grade A steel is supplied in the normalizing rolled condition or when special approval has been given for material thicker than 50 mm to be supplied in the as-rolled condition, a set of three impact test specimens are to be tested from each batch of 50 tonnes or fraction thereof.

2.4.5 Impact tests are generally not required for Grade B steel of 25 mm or less in thickness. However, the manufacturer is to confirm, by way of regular in-house tests, and on occasional material selected by the Surveyor, that the material meets the requirement in Table 3.2.3. The results of the tests are to be reported to the Surveyor. The frequency of the in-house checks are to be, as a minimum, one set of three impact test specimens for every 250 tonnes.

2.4.6 For Grade B steels of thicknesses above 25 mm, supplied in the as-rolled or normalizing rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the weight of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.7 For Grade B steels of thicknesses above 25 mm, supplied in the furnace normalized or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the weight of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

Table 3.2.3 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Charpy V-notch impact test (*see* Notes 3, 4, 5, 6 and 7)		
				Thickness mm	Average energy J minimum Longitudinal	Transverse (*see* Note 3)
A B D E	235	400 – 520 (*see* Note 1)	22 (*see* Note 2)	≤50 >50 ≤70 >70 ≤100	27 34 41	20 24 27

Impact tests are to be made on the various grades at the following temperatures:
A grade 20°C
B grade 0°C
D grade –20°C
E grade –40°C

NOTES
1. For sections in Grade A, the upper limit of the tensile strength range may be exceeded at the discretion of the Surveyor.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2), the minimum elongation is to be:

Thickness mm	≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤35	>35 ≤50
Elongation %	14	16	17	18	19	20	21	22

3. Generally, tests need only be made in the longitudinal direction. For special applications, transverse test specimens may be required by the purchaser or LR. Transverse test results for plates and wide flats are to be guaranteed by the supplier.
4. *See* 2.4.3 and 2.4.4.
5. *See* 2.4.5.
6. *See* 1.7.11.
7. *See* 2.4.12.

2.4.8 For Grade D steels supplied in the as-rolled or normalizing rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the weight of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.9 For Grade D steels, supplied in the furnace normalized or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the weight of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.10 For plates in Grade E steel, one set of three impact test specimens is to be made from each piece. For bars and sections in Grade E steel, one set of three test specimens is to be made from each 25 tonnes or fraction thereof. When, subject to the special approval of LR, sections are supplied in the as-rolled or normalizing rolled conditions, one set of impact tests is to be taken from each batch of 15 tonnes or fraction thereof.

2.4.11 The results of all tensile tests and the average energy values from each set of three impact tests are to comply with the appropriate requirements given in Table 3.2.3. For impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

2.4.12 For batch tested Grade B and D steel plates supplied in a condition other than furnace normalized, with a thickness equal to, or greater than 25 mm and 12 mm respectively, and where the average value of one set of tests is less than 40J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 40J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.2.3. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 2.3.2.

2.4.13 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.3.

2.5 Identification of materials

2.5.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted. Where a number of light materials are bundled, the bundle is to be identified in accordance with 1.10.2.

2.6 Certification of materials

2.6.1 At least two copies of each test certificate or shipping statement are to be provided. They are to give the information detailed in 1.11 and, additionally, are to indicate if sections in Grade A steel of rimming quality have been supplied. The chemical composition is to include the content of all the elements detailed in Table 3.2.1.

■ *Section 3* Higher strength steels for ship and other structural applications

3.1 Scope

3.1.1 Provision is made for material to be supplied in four strength levels, 27S, 32, 36 and 40.

3.1.2 The required notch toughness is designated by subdividing the strength levels into Grades AH, DH, EH and FH.

3.1.3 For the designation to fully identify a steel and its properties the appropriate grade letters should precede the strength level number, e.g. AH32 or FH40.

3.1.4 The requirements of this Section are primarily intended to apply to plates, wide flats, sections and bars not exceeding the thickness limits given in Table 3.3.1. For greater thicknesses, variations in the requirements may be permitted or required for particular applications but a reduction of the required impact energy is not allowed.

Table 3.3.1 Maximum thickness limits

Steel designation				Maximum thickness mm	
				Plates and wide flats	Sections and bars
AH 27S AH 32 AH 36 AH 40	DH 27S DH 32 DH 36 DH 40	EH 27S EH 32 EH 36 EH40	FH27S FH32 FH36 FH40	100	50

3.1.5 It should be noted that the fatigue strength of weldments in steels of high strength levels may not be greater than those of steels of lower strength levels.

3.2 Alternative specifications

3.2.1 Steels differing from the requirements of this Section in respect of chemical composition, deoxidation practice, condition of supply or mechanical properties may be accepted subject to special approval by LR. Such steels are to be given a special designation, *see* 3.7.2.

3.3 Manufacture

3.3.1 All the grades of steel are to be in the killed and fine grain treated condition.

3.4 Chemical composition

3.4.1 The chemical compositions of ladle samples for all grades of steel are to comply with the requirements given in Table 3.3.2.

3.4.2 The carbon equivalent is to be calculated from the ladle analysis using the formula given below and is not to exceed the maximum value agreed between the fabricator and the steelmaker when the steel is ordered.

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

For TM steels, the agreed carbon equivalent is not to exceed the values given in Table 3.3.3.

3.4.3 The cold cracking susceptibility, P_{cm}, may be used instead of the carbon equivalent for evaluating weldability, in which case the following formula is to be used for calculating the P_{cm} from the ladle analysis:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cr + Cu}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the manufacturing specification and reported on the certificate.

3.4.4 Small deviations in chemical composition from that given in Table 3.3.2 for plates exceeding 50 mm in thickness in Grades EH36, EH40, FH36 and FH40 may be approved provided that these deviations are documented and approved in advance.

3.4.5 Where the grain refining elements Niobium, Titanium and Vanadium are used either singly or in combination, the chemical composition is to be specifically approved for each Grade in combination with the rolling procedure to be used.

3.4.6 When any grade is supplied in an approved thermomechanically controlled processed condition, variations in the specified chemical composition may be considered, provided that these variations are documented and approved in advance.

3.5 Condition of supply

3.5.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.3.4 or Table 3.3.5. Where alternative conditions are permitted, these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material.

Table 3.3.2 Chemical composition

Grades	AH, DH, EH	FH
Carbon % max. Manganese % Silicon % max. Phosphorus % max. Sulphur % max.	0,18 0,9 – 1,60 (*see* Note 1) 0,50 0,035 0,035	0,16 0,9 – 1,60 0,50 0,025 0,025
Grain refining elements (*see* Note 2) Aluminium (acid soluble) % Niobium % Vanadium % Titanium % Total (Nb + V + Ti) % (*see* Note 5)	0,015 min. (*see* Note 3) 0,02 – 0,05 0,03 – 0,10 0,02 max. 0,12 max.	
Residual elements Nickel % max. Copper % max. Chromium % max. Molybdenum % max. Nitrogen % max.	 0,40 0,35 0,20 0,08 	 0,80 0,35 0,20 0,08 0,009 (0,012 max. if Al is present)

NOTES
1. For AH grade steels in all strength levels and thicknesses up to 12,5 mm, the specified minimum manganese content is 0,70%.
2. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.
3. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
4. Alloying elements other than those listed above are to be included in the approved manufacturing specification.
5. The grain refining elements are to be in accordance with the approved specification.

Table 3.3.3 Carbon equivalent requirements for higher tensile strength steels up to 100 mm in thickness when supplied in the TM condition

Grade				Carbon Equivalent, max. (%)	
				$t \leq 50$	$50 < t \leq 100$
AH 27S	DH 27S	EH 27S	FH 27S	0,36	0,38
AH 32	DH 32	EH 32	FH 32	0,36	0,38
AH 36	DH 36	EH 36	FH 36	0,38	0,40
AH 40	DH 40	EH 40	FH 40	0,40	0,42

NOTE
t = thickness in mm.

3.5.2 Where normalizing rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

3.5.3 The use of precipitation hardening steels is not acceptable, except where such hardening is incidental to the use of grain refining elements.

3.6 Mechanical tests

3.6.1 The results of all tensile tests and the average energy value from each set of three impact tests are to comply with the appropriate requirements given in Table 3.3.6.

3.6.2 For steels in the as-rolled, normalized, normalizing rolled or T.M. conditions, one tensile test is to be made for each batch of 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast.

Table 3.3.4 Conditions of supply for plates and wide flats

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)				
AH 27S AH 32 AH 36	Al or Al + Ti	≤20	AR	N	NR	TM	
		>20 ≤100	—	N	NR	TM	(*see* Note 3)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤12,5	AR	N	NR	TM	
		>12,5 ≤100	–	N	NR	TM	
AH 40	Any practice	≤12,5	AR	N	NR	TM	
		>12,5 ≤100	—	N	NR	TM	
DH 27S DH 32 DH 36	Al or Al + Ti	≤20	AR	N	NR	TM	
		>20 ≤100	—	N	NR	TM	(*see* Note 4)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤12,5	AR	N	NR	TM	
		>12,5 ≤100	—	N	NR	TM	
DH 40	Any practice	≤50	—	N	NR	TM	
		>50 ≤100	—	N	NR	TM	QT
EH 27S EH 32 EH 36	Any practice	≤100	—	N	—	TM	
EH 40	Any practice	≤100	—	N	—	TM	QT
FH 27S FH 32 FH 36 FH 40	Any practice	≤100	—	N	—	TM	QT

NOTES
1. Grain refining elements used singly or in any combination, require specific approval from Materials and NDE Department, London office.
2. AR = as-rolled N = furnace normalized NR = normalizing rolled
TM = thermomechanically controlled-rolled QT = quenched and tempered
3. Material up to 35 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.
4. Material up to 25 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.

3.6.3 For steels in the quenched and tempered condition a tensile test is to be made on each plate as heat treated. For continuously heat treated plates, one tensile test is to be made for each 50 tonnes or fraction thereof from a single cast. Additional tests are to be made for every variation of 10 mm in the thickness of the products from a single cast. The tensile test specimens are to be taken with their axes transverse to the main direction of rolling.

3.6.4 For products in the AH and DH grades, at least one set of three impact tests is to be made on the thickest piece in each batch of 50 tonnes when supplied in either the normalized or thermomechanically controlled condition. When the products are supplied in the as-rolled or normalizing rolled conditions a set of impact test specimens is to be taken from a different piece from each 25 tonnes or fraction thereof. When supplied in the quenched and tempered condition, a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

3.6.5 For plates and wide flats in the EH and FH grades supplied in the normalized or thermomechanically controlled conditions, one set of impact tests is to be made on each piece. For plates supplied in the quenched and tempered condition a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

3.6.6 For sections and bars in the EH and FH grades supplied in the normalized or thermomechanically controlled conditions, one set of impact tests is to be made on the thickest piece in a batch not exceeding 25 tonnes. For sections supplied in the as-rolled or normalizing rolled conditions the batch size is not to exceed 15 tonnes.

Table 3.3.5 Conditions of supply for sections and bars

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)			
AH 27S AH 32 AH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
AH 40	Any practice	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	
DH 27S DH 32 DH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
DH 40	Any practice	≤50	N	NR	TM	
EH 27S EH 32 EH 36	Any practice	≤50	N	TM		(*see* Notes 3 and 4)
EH 40	Any practice	≤50	N	TM	QT	
FH 27S FH 32 FH 36 FH 40	Any practice	≤50	N	TM	QT	(*see* Note 4)

NOTES
1. Grain refining elements used singly or in any combination require specific approval from Materials and NDE Department, London Office.
2. N = furnace normalized; NR = normalizing rolled; TM = thermomechanically controlled-rolled; QT = quenched and tempered
3. Subject to the special approval of LR, sections may be supplied in the as-rolled condition provided satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Subject to the special approval of LR, sections may be supplied in the NR condition.

3.6.7 For batch tested plates in a condition other than furnace normalized, with a thickness equal to 12 mm or greater, and where the average value of one set of tests is less than 50 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 50 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.3.6. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 3.5.2.

3.6.8 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.3.

3.7 Identification of materials

3.7.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint. Where a number of light products are bundled, the bundle is to be identified in accordance with 1.10.2.

3.7.2 Steels which have been specially approved and which differ from the requirements of this Section are to have the letter 'S' after the agreed identification mark.

3.8 Certification of materials

3.8.1 At least two copies of each test certificate or shipping statement are to be provided. They are to give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. The chemical composition is to include the contents of any grain refining elements used and of the residual elements.

3.8.2 For steels which have been specially approved, the agreed identification mark, the specified minimum yield stress and, if applicable, the contents of alloying elements are additionally to be stated on the test certificate or shipping statement.

3.8.3 The steelmaker is to provide the Surveyor with a written declaration as detailed in 1.11.2.

Table 3.3.6 **Mechanical properties for acceptance purposes** (*see* Note 1)

Grades (*see* Note 3)	Yield Stress N/mm^2 min.	Tensile Strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % min. (*see* Note 2)	Charpy V-notch impact tests (*see* Notes 4 and 5) Average energy J minimum					
				$t \leq 50$ mm		$50 < t \leq 70$ mm		$70 < t \leq 100$ mm	
				Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
AH 27S DH 27S EH 27S FH 27S	265	400 – 530	22	27	20	34	24	41	27
AH 32 DH 32 EH 32 FH 32	315	440 – 590	22	31	22	38	26	46	31
AH 36 DH 36 EH 36 FH 36	355	490 – 620 (*see* Note 3)	21	34	24	41	27	50	34
AH 40 DH 40 EH 40 FH 40	390	510 – 650	20	39	26	46	31	55	37

Impact tests are to be made on the various grades at the following temperatures:

AH grades 0°C
DH grades –20°C
EH grades –40°C
FH grades –60°C

NOTES
1. The requirements for products thicker than those detailed in the table are subject to agreement, *see* 3.1.4.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm, *see* Fig. 2.2.4 in Chapter 2, the minimum elongation is to be:

Thickness mm		≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤40	>40 ≤50	>50
Elongation %	Strength levels 27S, 32	14	16	17	18	19	20	21	22	To be specially agreed
	Strength level 36	13	15	16	17	18	19	20	21	
	Strength level 40	12	14	15	16	17	18	19	20	

3. Subject to special approval by LR, the minimum tensile strength may be reduced to 470 N/mm^2, for grades AH36, DH36, EH36 and FH36, in the TM condition when micro-alloying elements Nb, Ti or V are used singly and not in combination and provided the yield to tensile strength ratio does not exceed 0,89. For plates with a thickness ≤12 mm, the yield to tensile strength ratio is to be specially considered.
4. Generally, tests need only be made in the longitudinal direction. For special applications, transverse test specimens may be required by the purchaser or LR. Transverse properties for plates and wide flats are to be guaranteed by the supplier.
5. *See* 1.7.11
6. *See* 3.6.7.

■ *Section 4* Steels for boilers and pressure vessels

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and alloy steels intended for use in the construction of boilers and pressure vessels. In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements also give details of appropriate mechanical properties at elevated temperatures which may be used for design purposes.

4.1.2 Where it is proposed to use a carbon or carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and mechanical properties at elevated temperatures may be obtained by interpolation.

4.1.3 Carbon and carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2 but not exceeding 520 N/mm^2 may be accepted, provided that details of the proposed specification are submitted for approval.

4.1.4 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases the specified minimum tensile strength is not to exceed 600 N/mm^2.

4.1.5 Materials intended for use in the construction of the cargo tanks and process pressure vessels storage tanks for liquefied gases and for other low temperature applications are to comply with the requirements of Section 6 or 7, as appropriate.

4.2 Manufacture and chemical composition

4.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements of Table 3.4.1.

Table 3.4.1 Chemical composition and deoxidation practice

Grade of steel	Deoxidation	Chemical composition %						
Carbon and carbon-manganese steels		C max.	Si	Mn	P	S	Al	Residual elements
360 AR	Any method except rimmed steel	0,18	0,50 max.	0,40 – 1,20	0,040 max.		–	Cr 0,25 max. Cu 0,30 max. Mo 0,10 max. Ni 0,30 max. Total 0,70 max.
410 AR		0,21		0,40 – 1,30			–	
460 AR		0,23		0,80 – 1,50			–	
360	Any method except rimmed steel	0,17	0,35 max.	0,40 – 1,20	0,035 max.		–	
410		0,20		0,50 – 1,30			–	
460		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,40			–	
490	Killed		0,10 – 0,50	0,90 – 1,60			–	
360 FG	Killed fine grained	0,17	0,35 max.	0,40 – 1,20	0,035 max.		(*see* Note 2)	
410 FG		0,20		0,50 – 1,30				
460 FG		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,50				
490 FG			0,10 – 0,50	0,90 – 1,60				
510 FG		0,22						

Alloy steel		C	Si	Mn	P S	Al	Cr	Mo	Residual elements
13Cr Mo 45	Killed	0,10–0,18	0,15–0,35	0,4–0,8	0,035 max.	(*see* Note 3)	0,70–1,30	0,40–0,60	Cu 0,30 max.
11Cr Mo 910		0,08–0,18	0,15–0,50				2,00–2,50	0,90–1,10	Ni 0,30 max.

NOTES
1. For thicknesses greater than 30 mm, carbon 0,22% max.
2. Aluminium (acid soluble) 0,015% min. or
   Aluminium (total) 0,018% min.
   Niobium, vanadium or other suitable grain refining elements may be used either in place of or in addition to aluminium.
3. Aluminium (acid soluble or total) 0,020% max.

4.3 Heat treatment

4.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.4.2 except that, when agreed, material intended for hot forming may be supplied in the as-rolled condition.

Table 3.4.2 Condition of supply

Grade of steel	Condition of supply
Carbon and carbon-manganese 360 AR to 460 AR	As-rolled Maximum thickness or diameter is 40 mm
Carbon and carbon-manganese 360 to 490	Normalized or normalized rolled
Carbon and carbon-manganese 360 FG to 510 FG	Normalized or normalized rolled
13Cr Mo 45	Normalized and tempered
11Cr Mo 910	Normalized and tempered

4.4 Mechanical tests

4.4.1 For plates, a tensile test specimen is to be taken from one end of each piece when the mass does not exceed 5 tonnes and the length does not exceed 15 m. When either of these limits is exceeded, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

4.4.2 For strip, tensile test specimens are to be taken from both ends of each coil.

4.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

4.4.4 Where plates are required for hot forming and it has been agreed that the heat treatment will be carried out by the fabricator, the tests at the steelworks are to be made on material which has been cut from the plates and given a normalizing and tempering heat treatment in a manner simulating the treatment which will be applied to the plates.

4.4.5 If required by the Surveyors or by the fabricator, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties which can be accepted.

4.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Tables 3.4.3 to 3.4.5.

Table 3.4.3 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – As-rolled

Grade of steel	Thickness mm	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum
360 AR	≤ 40	190	360–480	24
410 AR	≤ 40	215	410–530	22
460 AR	≤ 40	240	460–580	21

Table 3.4.4 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – Normalized or normalized rolled

Grade of steel	Thickness mm (*see* Note)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum
360	>3 ≤16 >16 ≤40 >40 ≤63	205 195 185	360 – 480	26 26 25
410	>3 ≤16 >16 ≤40 >40 ≤63	235 225 215	410 – 530	24 24 23
460	>3 ≤16 >16 ≤40 >40 ≤63	285 255 245	460 – 580	22 22 21
490	>3 ≤16 >16 ≤40 >40 ≤63	305 275 265	490 – 610	21 21 20
360 FG	>3 ≤16 >16 ≤40 >40 ≤63	235 215 195	360 – 480	26 26 25
410 FG	>3 ≤16 >16 ≤40 >40 ≤63	265 245 235	410 – 530	24 24 23
460 FG	>3 ≤16 >16 ≤40 >40 ≤63	295 285 275	460 – 580	22 22 21
490 FG	>3 ≤16 >16 ≤40 >40 ≤63	315 315 305	490 – 610	21 21 21
510 FG	>3 ≤16 >16 ≤40 >40 ≤63	355 345 335	510 – 650	21

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

Table 3.4.5 Mechanical properties for acceptance purposes: alloy steels – Normalized and tempered

Grade of steel	Thickness mm (see Note)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum
13Cr Mo45	≤63	305	470–620	20
11Cr Mo910	≤16 >16 ≤63	275 265	480–630	18

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, e.g. for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

4.4.7 All test specimens are to be taken in the transverse direction unless otherwise agreed.

4.4.8 When material will be subject to strains in a through thickness direction, it is recommended that it should have specified through thickness properties in accordance with the requirements of Section 8.

4.5 Identification of materials

4.5.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted.

4.6 Certification of materials

4.6.1 Each test certificate or shipping statement is to give the information detailed in 1.11 together with general details of any heat treatment. The chemical composition is to include the content of all the elements detailed in Table 3.4.1.

4.7 Mechanical properties for design purposes

4.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Tables 3.4.6 to 3.4.8.

4.7.2 These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than given in Tables 3.4.6 to 3.4.8.

Table 3.4.6 Mechanical properties for design purposes (*see* 4.7.1) **: carbon and carbon-manganese steels – As-rolled**

Grade of steel	Thickness mm	Design temperature °C (*see* Note)						
		50	100	150	200	250	300	350
		Nominal minimum lower yield or 0,2% proof stress N/mm^2						
360 AR	≤ 40	154	153	152	145	128	108	102
410 AR	≤ 40	186	183	181	174	155	134	127
460 AR	≤ 40	218	213	210	203	182	161	153

NOTE
Maximum permissible design temperature is 350°C.

4.7.3 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on material from each cast. Where materials of more than one thickness are supplied from one cast, the thickest material is to be tested. The test specimens are to be prepared from material adjacent to that used for tests at ambient temperature. The axis of the test specimens is to be between mid and quarter thickness of the material and the test specimens are to be machined to dimensions in accordance with the requirements of Chapter 2. The test procedure is also to be as detailed in Chapter 2, and the results are to comply with the requirements of the National or proprietary specifications.

4.7.4 As an alternative to 4.7.3, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes but, at the discretion of the Surveyors, occasional check tests of this type may be requested.

4.7.5 Values for the estimated average stress to rupture in 100 000 hours are given in Table 3.4.9 and may be used for design purposes.

Table 3.4.7 Mechanical properties for design purposes (*see* 4.7.1)**: carbon and carbon-manganese steels – Normalized or controlled-rolled**

Grade of steel	Thickness mm (*see* Note)	Design temperature °C								
		50	100	150	200	250	300	350	400	450
		Nominal minimum lower yield or 0,2% proof stress N/mm²								
360	>3 ≤16	183	175	172	168	150	124	117	115	113
	>16 ≤40	173	171	169	162	144	124	117	115	113
	>40 ≤63	166	162	158	152	141	124	117	115	113
410	>3 ≤16	220	211	208	201	180	150	142	138	136
	>16 ≤40	204	201	198	191	171	150	142	138	136
	>40 ≤63	196	192	188	181	168	150	142	138	136
460	>3 ≤16	260	248	243	235	210	176	168	162	158
	>16 ≤40	235	230	227	220	198	176	168	162	158
	>40 ≤63	227	222	218	210	194	176	168	162	158
490	>3 ≤16	280	270	264	255	228	192	183	177	172
	>16 ≤40	255	248	245	237	214	192	183	177	172
	>40 ≤63	245	240	236	227	210	192	183	177	172
360 FG	>3 ≤16	214	204	185	165	145	127	116	110	106
	>16 ≤40	200	196	183	164	145	127	116	110	106
	>40 ≤63	183	179	172	159	145	127	116	110	106
410 FG	>3 ≤16	248	235	216	194	171	152	141	134	130
	>16 ≤40	235	228	213	192	171	152	141	134	130
	>40 ≤63	222	215	204	188	171	152	141	134	130
460 FG	>3 ≤16	276	262	247	223	198	177	167	158	153
	>16 ≤40	271	260	242	220	198	177	167	158	153
	>40 ≤63	262	251	235	217	198	177	167	158	153
490 FG	>3 ≤16	297	284	265	240	213	192	182	173	168
	>16 ≤40	293	279	260	237	213	192	182	173	168
	>40 ≤63	286	272	256	234	213	192	182	173	168
510 FG	>3 ≤63	313	290	270	255	235	215	200	180	—

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

Table 3.4.8 Mechanical properties for design purposes (*see* 4.7.1)**: alloy steels – Normalized and tempered**

Grade of steel	Thickness mm (see Note)	Design temperature °C									
		50	100	200	300	350	400	450	500	550	600
		Nominal minimum lower yield or 0,2% proof stress N/mm²									
13CrMo 45	>3 ≤63	284	270	248	216	203	199	194	188	181	174
11CrMo 910	>3 ≤63	255	249	233	219	212	207	194	180	160	137

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

Table 3.4.9 Mechanical properties for design purposes (*see* 4.7.5)**: estimated average values for stress to rupture in 100 000 hours (units N/mm²)**

Temperature °C	Grades of steel				
	Carbon and carbon-manganese			Low alloy	
	360FG 410FG 460FG	360 410 460	490 490FG 510FG	13CrMo 45	11CrMo 910
380	171	219	227	—	—
390	155	196	203	—	—
400	141	173	179	—	—
410	127	151	157	—	—
420	114	129	136	—	—
430	102	109	117	—	—
440	90	92	100	—	—
450	78	78	85	290	—
460	67	67	73	262	—
470	57	57	63	235	210
480	47	48	55	208	186
490	36	—	47	181	165
500	—	—	—	155	145
510	—	—	—	129	128
520	—	—	—	103	112
530	—	—	—	80	98
540	—	—	—	62	84
550	—	—	—	49	72
560	—	—	—	42	61
570	—	—	—	36	51
580	—	—	—	—	44

■ *Section 5* Steels for machinery fabrications

5.1 General

5.1.1 Steel plates, sections or bars intended for use in the construction of major components of welded machinery structures, such as bedplates, crankcases, frames and entablatures, are to comply with one of the following alternatives:

(a) Any grade of normal strength structural steel as detailed in Section 2.

(b) Any grade of higher tensile structural steel as detailed in Section 3.

(c) Any grade of carbon-manganese boiler or pressure vessel steel as detailed in Section 4, except that for this application batch testing is acceptable. The size of a batch and the number of tensile tests are to be as detailed in Section 2.

5.1.2 The minus tolerances for plates and wide flats are to be in accordance with Table 3.5.1.

Table 3.5.1 Under thickness tolerances

Nominal thickness (mm)	Under thickness tolerance (mm)
≥5 <8	–0,4
≥8 <15	–0,5
≥15 <25	–0,6
≥25 <40	–0,8
≥40	–1,0

■ *Section 6* Ferritic steels for low temperature service

6.1 Scope

6.1.1 This Section gives specific requirements for carbon-manganese and nickel alloy steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases.

6.1.2 The requirements of this Section are also applicable for other types of pressure vessels where the use of steels with guaranteed impact properties at low temperatures is required.

6.1.3 Provision is made for plates and sections up to 40 mm thick.

6.1.4 Steels with alternative chemical compositions or mechanical properties or in a different supply condition may be given special consideration.

6.2 Manufacture and chemical composition

6.2.1 All steels are to be in the killed and fine grain treated condition.

6.2.2 The chemical compositions of carbon-manganese steels are to comply with the appropriate requirements for Grades AH, DH, EH and FH strength levels 27S, 32, 36 and 40, *see* Table 3.3.2. For the uses defined in 6.1.1 and 6.1.2, however, these grades are to be designated LT–AH, LT–DH, LT–EH and LT–FH respectively.

6.2.3 The chemical compositions of nickel alloy steels are to comply with the appropriate requirements of Table 3.6.1.

6.3 Heat treatment

6.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.6.2.

Table 3.6.1 Chemical compositions of nickel alloy steels

<table>
<tr><th>Grade of steel</th><th>C</th><th>Si</th><th>Mn</th><th>Ni</th><th>P</th><th>S</th><th>Residual elements</th><th>Aluminium</th></tr>
<tr><td>$1\frac{1}{2}$ Ni</td><td>0,18 max.</td><td rowspan="4">0,10 – 0,35</td><td>0,30 – 1,50</td><td>1,30 – 1,70</td><td rowspan="4">0,025 max.</td><td rowspan="4">0,020 max.</td><td rowspan="4">Cr 0,25 max.
Cu 0,35 max.
Mo 0,08 max.
Total 0,60 max.</td><td rowspan="4">Total 0,020% min.

Acid soluble 0,015% min.</td></tr>
<tr><td>$3\frac{1}{2}$ Ni</td><td>0,15 max.</td><td rowspan="3">0,30 – 0,90</td><td>3,20 – 3,80</td></tr>
<tr><td>5Ni</td><td>0,12 max.</td><td>4,70 – 5,30</td></tr>
<tr><td>9Ni</td><td>0,10 max.</td><td>8,50 – 10,0</td></tr>
</table>

Table 3.6.2 Supply conditions

<table>
<tr><th>Grade</th><th>Plates</th><th>Sections and bars</th></tr>
<tr><td>LT – AH</td><td rowspan="2">N TM</td><td rowspan="3">Any</td></tr>
<tr><td>LT – DH</td></tr>
<tr><td>LT – EH</td><td rowspan="2">Normalized (see Note)
T.M.C.P.
Quenched and tempered</td></tr>
<tr><td>LT – FH</td><td>N TM</td></tr>
<tr><td>$1\frac{1}{2}$ Ni
$3\frac{1}{2}$ Ni
5Ni</td><td colspan="2">Normalized (see Note)
Normalized and tempered
Quenched and tempered</td></tr>
<tr><td>9Ni</td><td colspan="2">Double normalized and tempered
Quenched and tempered</td></tr>
<tr><td colspan="3">NOTE
Where the term ‘Normalized’ is used it does not include normalizing rolling.</td></tr>
</table>

6.4 Mechanical tests

6.4.1 For plates, a tensile test specimen is to be taken from one end of each piece when the mass does not exceed 5 tonnes and the length does not exceed 15 m. When either of these limits is exceeded, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

6.4.2 For strips, tensile test specimens are to be taken from both ends of each coil.

6.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

6.4.4 One set of three Charpy V-notch impact test specimens is to be taken for each tensile test specimen required.

6.4.5 For plates, these impact test specimens are to be cut with the principal axis perpendicular to the final direction of rolling. For sections, the impact test specimens are to be taken longitudinally.

6.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Table 3.6.3. The ratio between the yield stress and the tensile strength is not to exceed 0,9 for normalized and TM steels and 0,94 for QT steels.

6.4.7 The average value for the three impact tests is to comply with the appropriate requirements given in Table 3.6.3. One individual value may be less than the required value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

6.4.8 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.3.

6.5 Identification of materials

6.5.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted.

6.6 Certification of materials

6.6.1 Each test certificate or shipping statement is to give the information detailed in 1.11 together with general details of the heat treatment. The chemical composition is to include the content of all the elements detailed in Tables 3.3.2 or 3.6.1.

Table 3.6.3 **Mechanical properties for acceptance purposes** (*see* Note 1)

Grade of steel		Yield stress N/mm^2 min.	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % min.	Charpy V-notch impact tests (*see* Note 3)	
					Test temp. °C	Impact energy
LT – AH	27S	265	400 – 530	22	0	Plates – transverse tests Average energy 27 J min Sections and bars – longitudinal tests Average energy 41 J min
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
LT – DH	27S	265	400 – 530	22	–20	
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
LT – EH	27S	265	400 – 530	22	–40	
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
LT – FH	27S	265	400 – 530	22	–60	
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
$1\frac{1}{2}$ Ni		275	490 – 640	22	–65	
$3\frac{1}{2}$ Ni		285	450 – 610	21	–95	
5Ni		390	540 – 740	21	–110	
9Ni		490	640 – 790	18	–196	

NOTES
1. These requirements are applicable to products not exceeding 40 mm in thickness. The requirements for thicker products are subject to agreement.
2. The minimum design temperatures at which plates of different thicknesses in the above grades may be used are given in Fig. 3.6.1 and Fig. 3.6.2. Consideration will be given to the use of thicknesses greater than those in the Tables or to the use of design temperatures below –165°C.
3. Impact tests are not required on thicknesses less than 6 mm.

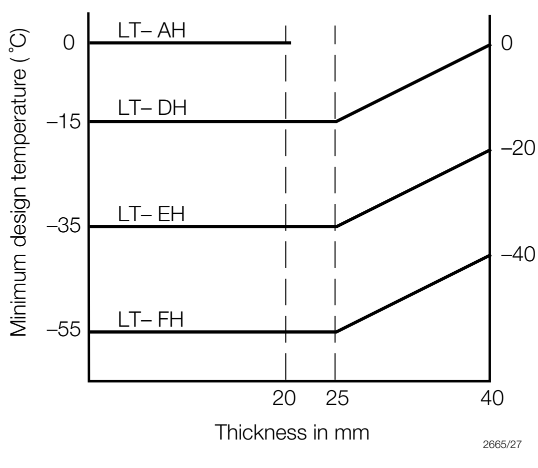


Fig. 3.6.1
Minimum design temperatures for carbon-manganese grades

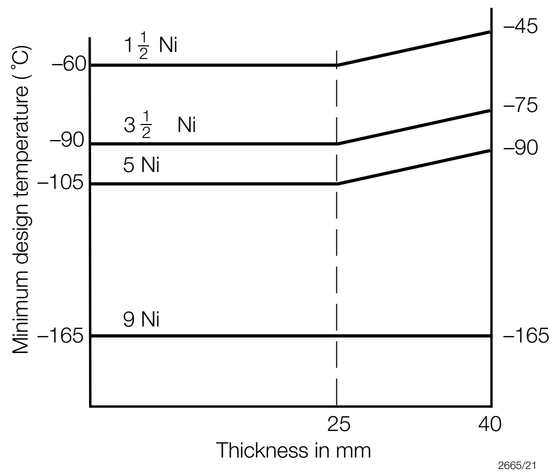


Fig. 3.6.2
Minimum design temperatures for nickel grades

■ *Section 7* Austenitic and duplex stainless steels

7.1 Scope

7.1.1 Provision is made in this Section for rolled products in austenitic and duplex (austenite plus ferrite) stainless steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for chemicals and liquefied gases.

7.1.2 Austenitic stainless steels are suitable for applications where the lowest design temperature is not lower than –165°C.

7.1.3 Austenitic stainless steels are also suitable for service at elevated temperatures, and for such applications the proposed specification should contain, in addition to the requirements of 7.1.6, minimum values for 0,2 and 1,0 per cent proof stresses at the design temperature.

7.1.4 Duplex stainless steels are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels below 0°C will be subject to special consideration.

7.1.5 Duplex stainless steels are also suitable for service at temperatures up to 300°C, and for such applications the proposed specification should include, in addition to the requirements of 7.1.6, a minimum value for 0,2 per cent proof stress at the design temperature.

7.1.6 A specification giving details of the chemical composition, heat treatment and mechanical properties, including, for the austenitic grades, both the 0,2 and 1,0 per cent proof stresses, is to be submitted for consideration and approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 3.7.1.

7.2.2 Consideration will be given to the use of steels whose compositions are outside the scope of Table 3.7.1.

7.3 Heat treatment

7.3.1 All materials are to be supplied in the solution treated condition.

7.4 Mechanical tests

7.4.1 Tensile test specimens are to be taken in accordance with the appropriate requirements of 4.4 and 6.4.1.

7.4.2 For the duplex grades, one set of three Charpy V-notch impact test specimens machined from the longitudinal direction for each tensile test is to be tested at –20°C. The average energy value of the three specimens is to be not less than 41 Joules.

7.4.3 Unless otherwise agreed, impact tests are not required from the austenitic grades of steel given in this Section.

Table 3.7.1 Chemical composition

Type and grade of steel	Chemical composition % (*see* Note)								
	C	Si	Mn	P	S	Cr	Ni	Mo	N	Other
Austenitic										
304 L						17,0—20,0	8,0—13,0	—	0,10	—
304 LN						17,0—20,0	8,0—12,0	—	0,10—0,22	—
316 L	0,03					16,0—18,5	10,0—15,0	2,0—3,0	0,10	—
316 LN		1,0	2,0	0,045	0,03	16,0—18,5	10,0—14,5	2,0—3,0	0,10—0,22	—
317 L						18,0—20,0	11,0—15,0	3,0—4,0	0,10	—
317 LN						18,0—20,0	12,5—15,0	3,0—4,0	0,10—0,22	—
321	0,08					17,0—19,0	9,0—12,0	—	0,10	5 x C ≤ Ti ≤ 0,7
347	0,08					17,0—19,0	9,0—13,0	—	0,10	10 x C ≤ Nb ≤ 1,0
Duplex										
UNS S 31803	0,03	1,0	2,0	0,03	0,02	21,0—23,0	4,5—6,5	2,5—3,5	0,08—0,20	—
UNS S 32750	0,03	0,80	1,2	0,035	0,02	24,0—26,0	6,0—8,0	3,0—5,0	0,24—0,32	Cu 0,50 max.

NOTE
All figures are a maximum value except where a range is shown.

7.4.4 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.3.

7.4.5 The results of all tensile tests are to comply with the requirements of Table 3.7.2 or the approved specification.

7.5 Through thickness tests

7.5.1 Where material will be strained in a through thickness direction during welding or in service, through thickness tests are required on plates over 10 mm thick in all the grades of steels listed in Table 3.7.1, apart from Grades 304L, 304 LN, 321 and 347.

7.5.2 Testing is to conform with the requirements of Section 8, with the exception given in 7.5.3.

7.5.3 When the reduction in area is less than 35 per cent, metallographic or other evidence is required to show that no significant amount of any detrimental phase, such as sigma, is present.

7.6 Intergranular corrosion tests

7.6.1 For certain specific applications such as storage tanks for chemicals, it may be necessary to demonstrate that the material used is not susceptible to intergranular corrosion resulting from grain boundary precipitation of chromium-rich carbides.

7.6.2 When required, one test of this type is to be carried out for each tensile test. The material for the test is to be taken adjacent to that for the tensile test.

7.6.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be as given in 7.6.4, *see* Ch 2,8.

7.6.4 Wherever practical, exposed cut edges should be avoided. However, where any such edges are to remain after fabrication is completed it is to be shown by an appropriate test that the corrosion resistance is adequate for the cargoes expected to be encountered.

7.7 Clad plates

7.7.1 Carbon or carbon-manganese steel plates, clad on one or both surfaces with a suitable grade of austenitic or duplex stainless steel, may be used for the construction of cargo or storage tanks for chemicals.

7.7.2 The carbon or carbon-manganese steel base plates are to comply with the requirements of Section 4, and the austenitic cladding material generally with the requirements of this Section.

7.7.3 The process of manufacture is to be specially approved and may be either by roll cladding or by explosive bonding.

7.7.4 Where the use of clad materials is proposed, the material specification is to be submitted for consideration, together with details of the extent, and the acceptance standards for non-destructive examination.

7.8 Identification of materials

7.8.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted.

7.9 Certification of materials

7.9.1 Each test certificate or shipping statement is to give the information detailed in 1.11, together with general details of heat treatment and, where applicable, the results obtained from intercrystalline corrosion tests. The chemical composition is to include the content of all the elements detailed in Table 3.7.1.

Table 3.7.2 Mechanical properties for acceptance purposes

Type and grade of steel	0,2% Proof stress (N/mm^2) minimum	1% Proof stress (N/mm^2) minimum	Tensile strength (N/mm^2) minimum	Elongation on $5,65\sqrt{S_o}$ % minimum
Austenitic				
304L	170	210	485	40
304LN	205	245	515	40
316L	170	210	485	40
316LN	205	245	515	40
317L	205	245	515	40
317LN	240	280	550	40
321	205	245	515	40
347	205	245	515	40
Duplex				
UNS S 31803	450	—	620	25
UNS S 32750	550	—	795	15

Section 8
Plates with specified through thickness properties

8.1 Scope

8.1.1 Provision is made in this Section for 'Z' grade plate and wide flat material with improved ductility in the through thickness or 'Z' direction, *see* Fig. 3.8.1. The use of this material is recommended for certain types of welded structures (*see* 1.2) in order to minimize the possibility of lamellar tearing either during fabrication or erection.

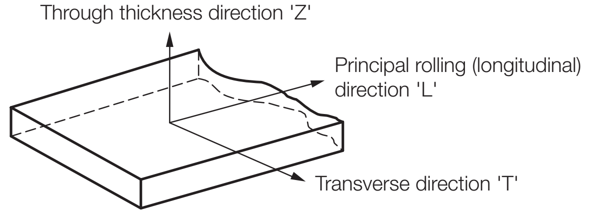


Fig. 3.8.1 Schematic of testing directions

8.1.2 Through thickness properties are characterised by specified values for reduction of area in a through thickness tensile test.

8.1.3 Provision is made for two grades Z25 and Z35. For normal ship applications the Z25 grade is applicable, whilst the Z35 grade is for more severe applications.

8.1.4 This 'Z' grade material is to comply with the requirements of Sections 2, 3, 4, 5 and 6 as appropriate, and the additional requirements of this Section.

8.1.5 The test procedure detailed in this Section may also be used to demonstrate that no unacceptable amount of banding of any detrimental phase, such as sigma is present, *see* 7.5.

8.2 Manufacture

8.2.1 All plates and wide flats are to be manufactured at works which have been approved by LR for this quality of material.

8.2.2 It is recommended that the steel should be efficiently vacuum de-gassed. The sulphur content is not to exceed 0,008 per cent.

8.2.3 Consideration will be given to proposals for alternative methods of improving through thickness properties.

8.3 Test material

8.3.1 Unless otherwise agreed, through thickness tensile tests are only required for plate materials where the thickness exceeds 15 mm for carbon and alloy steels or 10 mm in the case of austenitic and duplex stainless steels.

8.3.2 For plates and wide flats, one test sample is to be taken close to the longitudinal centreline from one end of each rolled piece representing the batch, *see* Table 3.8.1 and Fig. 3.8.2. The test sample must be large enough to accommodate the preparation of 6 specimens. 3 test specimens are to be prepared while the rest of the sample remains for possible retest.

Table 3.8.1 Batch size dependent on product and sulphur content

Product	*S* > 0,005%	*S* ≤ 0,005%
Plates	Each piece (parent plate)	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness ≤ 25 mm	Maximum 10 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness > 25 mm	Maximum 20 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment

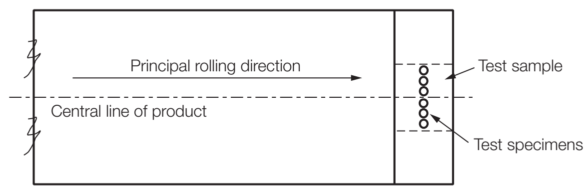


Fig. 3.8.2
Plate and wide flat sampling position

8.3.3 The dimensions of the test specimens are to be in accordance with Ch 2,2.1.12.

8.3.4 Alternatively, test sampling may be carried out in accordance with an accepted National or International Standard.

8.4 Mechanical tests

8.4.1 The three through thickness tensile test specimens are to be tested at ambient temperature and for acceptance are to give a minimum average reduction of area value of not less than that shown in Table 3.8.2. Only one individual value may be below the minimum average, but should not be less than the minimum individual value shown for the appropriate grade.

Table 3.8.2 Reduction of area acceptance values

Grade	Z25	Z35
Minimum average	25%	35%
Minimum individual	15%	25%

8.4.2 If the average value fails to comply with 8.4.1, three additional tests may be made on specimens from the same test sample. The results of these tests are to be added to those previously obtained to form a new average, which for acceptance is to be not less than 25 per cent for grade Z25 or 35 per cent for grade Z35. No individual results in the re-test shall be below 25 per cent for grade Z25 or 35 per cent for grade Z35, *see* Fig. 3.8.3.

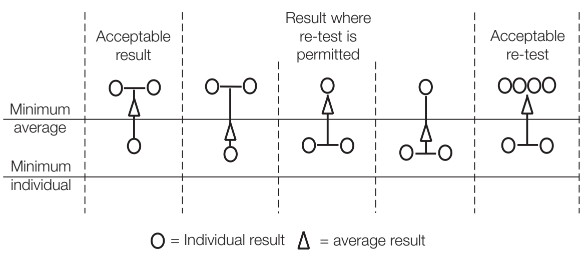


Fig. 3.8.3
Diagram showing acceptance/rejection and re-test criteria

8.4.3 Where batch testing is permitted, and failure after re-test occurs, the tested piece is to be rejected. Each remaining piece in the batch may be individually tested and accepted based on satisfactory results.

8.4.4 If the fracture of a test specimen occurs in the weld or in the heat affected zone the test is to be regarded as invalid and is to be repeated on a new test specimen.

8.5 Non-destructive examination

8.5.1 All 'Z' grade plates are to be ultrasonically tested in the final supply condition with a probe frequency of 3-5 MHz. The testing is to be performed in accordance with either EN 10160 Level S1/E1 or ASTM A 578 Level C.

8.6 Identification of materials

8.6.1 Products which comply with the requirements of this Section are to have the notation Z25 or Z35 added to the steel grade designation.

8.7 Certification

8.7.1 The following information is required to be included on the certificate in addition to the appropriate steel grade requirements:
(a) Through thickness reduction in area (%), individual results and average.
(b) Steel grade with Z25 or Z35 notation.

■ *Section 9* Bars for welded chain cables

9.1 Scope

9.1.1 Provision is made in this Section for rolled steel bars intended for the manufacture of three Grades (U1, U2 and U3) of stud link chain cable for the anchoring and mooring of ships and three Grades (R3, R3S and R4) of offshore mooring cable.

9.1.2 For the ship grades, U1, U2 and U3, approval will permit the supply of bars of the appropriate grades and size to any chain cable manufacturer.

9.1.3 For the offshore grades, R3, R3S and R4, approval is confined to bar to be supplied to a nominated chain manufacturer and will be given only after successful testing of a completed chain. Separate approvals are required if bar is to be supplied to more than one cable manufacturer.

9.1.4 For all grades, approval is normally given for diameters of bars no greater than those of the bars used in procedure tests.

9.2 Manufacture

9.2.1 All bar material is to be made from killed steel and, except for Grade U1 chain cables, is to be fine grained.

9.2.2 The bars are to be made to a specification approved by LR which should include the manufacturing procedure, deoxidation practice, heat treatment and mechanical properties.

9.3 Chemical composition

9.3.1 For Grades U1, U2 and U3 the chemical composition should be generally within the limits given in Table 3.9.1.

9.3.2 For Grades R3, R3S and R4 the chemical composition is to comply with an approved specification, *see* 9.2.2.

Table 3.9.1 Chemical composition of killed steel bars

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	Nb max.	V max.	N max.	Cr max.	Cu max.	Ni max.	Mo max.
U1	0,20	0,15–0,35	0,40 min.	0,04	0,04	–	–	–	–	–	–	–	–
U2	0,24	0,15–0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	–	–	–	–	–	–	–
U3	0,33	0,15–0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,05 *see* Note 2	0,10 *see* Note 2	0,015	0,25	0,35	0,40	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

9.3.3 For Grade R4 chain cable the steel should contain a minimum of 0,2 per cent molybdenum. The reported composition is to include the contents of antimony, arsenic, tin, copper, nitrogen, aluminium and titanium.

9.4 Heat treatment

9.4.1 Unless stipulated otherwise, the bars are to be supplied in the as-rolled condition, but the supplier is to be advised by the chain manufacturer of the heat treatment to be used for the completed chain in order that the mechanical test specimens may be tested in the condition of heat treatment used for the chain.

9.4.2 For Grades U1 and U2, the samples selected from each batch may be tested either in the as-rolled condition or after heat treatment in full cross-section and in a manner simulating the heat treatment applied to the finished cable.

9.4.3 For Grades U3, R3, R3S and R4 the sample is to be tested after heat treatment as detailed in 9.4.2.

9.5 Embrittlement tests

9.5.1 For Grades R3, R3S and R4 the bar manufacturer is to provide evidence that the material is not susceptible to strain ageing or to temper brittleness under the conditions of manufacture of the chain. The results of the relevant tests are to be reported to LR at the approval stage. Approval will be restricted to the specified steel composition and if later this is altered then re-approval will be required. Temper brittleness testing may be waived if the chain is to be quenched after tempering.

9.5.2 Each heat of grade R3S and R4 steel bars is to be tested for hydrogen embrittlement (*see* Ch 2,5.3). In the case of continuous casting, test samples representing both the beginning and the end of the charge are to be taken. In the case of ingot casting, test samples representing two different ingots are to be taken.

9.5.3 Each sample is to be heat treated in a manner simulating the heat treatment of the finished chain. From each sample two specimens are to be prepared from the mid-diameter of the bar and tested in accordance with Ch 2,5.3.

9.5.4 The ratio Z_1/Z_2 is to be greater than or equal to 0,85, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

9.5.5 If the requirement is not met, the material is to be subjected to a hydrogen degassing treatment which is subject to approval by LR. Further tests are to be performed after degassing.

9.6 Mechanical tests

9.6.1 Bars of the same nominal diameter are to be presented for test in batches of 50 tonnes or fraction thereof from the same cast. A suitable length from one bar in each batch is to be selected for test purposes.

9.6.2 For all grades, one tensile test is to be taken from each sample length selected. Additionally, for Grades U3, R3, R3S and R4 material, one set of three Charpy V-notch impact test specimens is to be prepared. Impact tests are also required for Grade U2 when the chain is to be supplied in as-welded condition.

9.6.3 The results of all tensile and, where applicable, impact tests are to be in accordance with the appropriate requirements of Table 3.9.2.

9.7 Dimensional tolerances

9.7.1 The tolerances on diameter and ovality of the bar are to be in accordance with Table 3.9.3.

9.8 Non-destructive examination

9.8.1 For the R3, R3S and R4 grades all bars are to be inspected by a magnetic particle or eddy current method and are also to be subjected to ultrasonic examination.

9.8.2 The frequency of non-destructive testing may be reduced at the discretion of LR, provided statistical evidence is available that the required quality is achieved consistently.

Table 3.9.2 Mechanical properties

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests		
					Test temperature °C	Average energy J minimum	Average energy flash weld J minimum
U1	–	370–490	25	—	—	—	—
U2	295	490–690	22	—	0 (*see* Note 1)	27	—
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35	— —
R3	410 (*see* Note 3)	690 minimum (*see* Note 3)	17	50	0 –20 (*see* Note 2)	60 40	50 30
R3S	490 (*see* Note 3)	770 minimum (*see* Note 3)	15	50	0 –20 (*see* Note 2)	65 45	53 33
R4	580 (*see* Note 3)	860 minimum (*see* Note 3)	12	50	–20	50	36

NOTES
1. Impact tests may be waived when the chain cable is to be supplied in one of the heat treated conditions given in Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C, at the option of LR.
3. The ratio of yield strength to tensile strength should not exceed 0,92.

Table 3.9.3 Dimensional tolerance of bar stock

Nominal diameter mm	Tolerance on diameter mm	Tolerance on roundness ($d_{max} - d_{min}$) mm
≤25	–0/+1,0	0,60
>26 ≤35	–0/+1,2	0,80
>36 ≤50	–0/+1,6	1,10
>51 ≤80	–0/+2,0	1,50
>81 ≤100	–0/+2,6	1,95
>101 ≤120	–0/+3,0	2,25
>121 ≤160	–0/+4,0	3,00

9.9 Identification

9.9.1 Each bar is to be identified in accordance with 1.10 and, in addition, is to be marked with the appropriate grade of chain cable.

9.10 Certification

9.10.1 Each consignment of bars is to be accompanied by a certificate in accordance with 1.11 but with the addition of the grade of chain cable.

■ *Section 10* High strength quenched and tempered steels for welded structures

10.1 Scope

10.1.1 Provision is made in this Section for weldable high strength quenched and tempered steel plates and wide flats up to 70 mm thick. However, special consideration will be given to thicknesses up to 50 mm supplied in the TM rolled condition.

10.1.2 Plates and wide flats exceeding 70 mm in thickness as well as other product forms may also be supplied in accordance with the requirements of this Section provided that the prior agreement of LR is obtained.

10.1.3 The steels may be supplied in six strength levels with minimum yield stresses of 420, 460, 500, 550, 620 and 690 N/mm^2 respectively.

10.1.4 Each strength level is sub-divided into four grades AH, DH, EH and FH, differing essentially in the required levels of notch toughness.

10.1.5 For the designation to fully identify a steel and its properties, the appropriate grade letter should precede the strength level number, e.g. EH 42.

10.1.6 Steels differing in strength level, mechanical properties and chemical composition from those detailed in this Section may be supplied, subject to special approval from LR. Such steels are to have the letter 'S' after the agreed identification mark.

10.2 Manufacture and chemical composition

10.2.1 The steels are to be fully killed and fine grain treated.

10.2.2 The chemical composition is to comply with the requirements of the approved manufacturing specification and the limits set in Table 3.10.1.

Table 3.10.1 Chemical composition

Grade	AH	DH EH	FH
Carbon % max	0,21	0,20	0,18
Manganese % max	1,70	1,70	1,60
Silicon % max	0,55	0,55	0,55
Phosphorus % max	0,035	0,030	0,025
Sulphur % max	0,035	0,030	0,025
Nitrogen % max	0,020	0,020	0,020
Grain refining elements (*see* Note 1)			
Aluminium (acid soluble) % min (*see* Note 2)		0,015	
Niobium %		0,02—0,05	
Vanadium %		0,03—0,10	
Titanium % max		0,02	
Total (Nb + V + Ti) % max		0,12	

NOTES
1. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the content is to be within the limits given in the Table. When used in combination, these limits are not applicable but the proportions of the grain refining elements are to be in accordance with the approved manufacturing specification.
2. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is not to be less than 0,020%.
3. Alloying elements and residual elements other than those listed in the Table (e.g. Ni, Cr, Cu, Mo and B) are to be included in the approved manufacturing specification.

10.2.3 The cold cracking susceptibility, P_{cm}, may be used as an alternative to the carbon equivalent for evaluating weldability. It is to be calculated from the ladle analysis using the following formula:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cr + Cu}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the approved manufacturing specification.

10.3 Mechanical properties

10.3.1 At least one tensile test piece and one set of three Charpy V-notch impact tests specimens are to be taken from each piece as heat treated.

10.3.2 For continuously heat treated products, one tensile test piece and a set of three impact test specimens are to be taken from each plate as heat treated.

10.3.3 For plates and wide flats with widths exceeding 600 mm, the tensile and impact test specimens are to be taken with their axes transverse to the final direction of rolling. For other products, the impact test specimens are to be taken in the longitudinal direction but the tensile test specimens may be taken in either the longitudinal or transverse direction as agreed with LR.

10.3.4 The results of all tests are to comply with the appropriate requirements of Table 3.10.2.

10.3.5 Where standard subsidiary impact test specimens are necessary, *see* Ch 2,3.2.3.

10.4 Identification of materials

10.4.1 The particulars detailed in 1.10 are to be marked on each piece which has been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint.

10.5 Certification of materials

10.5.1 At least two copies of each test certificate or shipping statement are to be provided. They are to give the information detailed in 1.11. The chemical composition is to include the contents of all the elements detailed in Table 3.10.1.

Table 3.10.2 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm^2 min. (*see* Note 1)	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum (*see* Note 2)		Charpy V-notch impact tests (*see* Note 4)		
					Test temperature	Average energy J minimum	
			Transverse	Longitudinal	°C	Transverse	Longitudinal
AH 42 DH 42 EH 42 FH 42	420	530 – 680	18	20	0 –20 –40 –60	28	42
AH 46 DH 46 EH 46 FH 46	460	570 – 720	17	19	0 –20 –40 –60	31	46
AH 50 DH 50 EH 50 FH 50	500	610 – 770	16	18	0 –20 –40 –60	33	50
AH 55 DH 55 EH 55 FH 55	550	670 – 830	16	18	0 –20 –40 –60	37	55
AH 62 DH 62 EH 62 FH 62	620	720 – 890	15	17	0 –20 –40 –60	41	62
AH 69 DH 69 EH 69 FH 69	690	770 – 940	14	16	0 –20 –40 –60	46	69

NOTES

1. Where a distinct yield stress indication is not obtainable during tensile testing the 0,2% proof stress is applicable.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2) the minimum elongation is to be:

Thickness mm		≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤40	>40 ≤50	>50 ≤70
Strength levels								
Elongation %	42	11	13	14	15	16	17	18
	46	11	12	13	14	15	16	17
	50 and 55	10	11	12	13	14	16	16
	62	9	11	12	12	13	14	15
	69	9	10	11	11	12	13	14

These values apply to transverse specimens. Where the use of longitudinal specimens has been agreed, the values are to be increased by 2%.

3. The ratio of yield strength to tensile strength should not exceed 0,94.
4. Impact tests are not required on thicknesses less than 6 mm.

Section

■ *Section 1*
General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Castings are to be made at foundries approved by LR. The steel used is to be manufactured by a process approved by Lloyd's Register (hereinafter reffered to as 'LR').

1.2.2 All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognized good practice and is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the chemical composition and/or thickness of the casting. The affected areas are to be either machined or ground smooth for a depth of about 2 mm unless it has been shown that the material has not been damaged by the cutting process. Special examination will be required to find any cracking in way of the cut surfaces.

1.2.3 Where two or more castings are joined by welding to form a composite item, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests will be required, *see also* the requirements of 1.9.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved specification.

1.3.2 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.3.3 The locations of all chaplets are to be noted and to be subject to close visual inspection (and when necessary ultrasonic examination) to ensure complete fusion.

1.4 Chemical composition

1.4.1 All castings are to be made from killed steel. The chemical composition of the ladle sample is to be within the limits given in the relevant Section of this Chapter. Where general overall limits are specified, the chemical composition is to be appropriate for the type of steel, dimensions and required mechanical properties of the castings.

1.4.2 Except where otherwise specified, suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.5 Heat treatment

1.5.1 All castings are to be heat treated in accordance with the requirements given in the relevant Section of this Chapter.

1.5.2 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means of temperature control and is fitted with pyrometers which measure and record the temperature of the furnace charge. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. Sufficient thermocouples are to be connected to the furnace charge to show that its temperature is adequately uniform and the temperatures are to be recorded throughout the heat treatment. Alternative procedures are to be approved by LR, Materials and NDE department. Copies of these records are to be presented to the Surveyor together with a sketch showing the positions at which the temperature measurements were carried out. The records are to identify the furnace that was used and give details of the charge, the heat treatment temperature and time at temperature and the date. The Surveyor is to examine the charts and confirm the details on the certificate. In the case of very large components which require heat treatment, alternative methods will be specially considered.

1.5.3 If a casting is locally reheated, or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses.

1.6 Test material and test specimens

1.6.1 Test material sufficient for the tests specified in Sections 2 to 9 and for possible re-test purposes is to be provided for each casting. The test samples are to be either integrally cast or gated to the casting and are to have a thickness of not less than 30 mm.

1.6.2 The test samples are not to be detached from the casting until the heat treatment specified in 1.5.1 has been completed and they have been properly identified.

1.6.3 As an alternative to 1.6.1 and 1.6.2, where a number of small castings of about the same size, each of which is under 1000 kg in mass, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted, using separately cast test samples of suitable dimensions. The test samples are to be properly identified and heat treated together with the castings which they represent. At least one test sample is to be provided for each batch of castings.

1.6.4 The test specimens are to be prepared in accordance with the requirements of Chapter 2. Tensile test specimens are to have a cross-sectional area of not less than 150 mm^2.

1.6.5 Re-test procedures are to be in accordance with Ch 2,1.4.

1.7 Visual and non-destructive examination

1.7.1 All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting.

1.7.2 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.7.3 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.7.4 All castings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces. Castings are to be subject to magnetic particle examination in accordance with 1.7.8, unless more specific requirements for non-destructive examination are included in subsequent Sections of this Chapter, other parts of the Rules or the agreed specification.

1.7.5 Where specified or required by the Rules non-destructive examination is to be carried out before acceptance. All tests are to be carried out by competent operators using reliable and efficiently maintained equipment. The testing procedures are to be acceptable to the Surveyor.

1.7.6 The manufacturer is to provide the Surveyor with a signed statement confirming that non-destructive examination has been carried out and that such inspection has not revealed any significant defects. Brief details of the testing procedure used are also to be included in this statement.

1.7.7 Where magnetic particle examination is specified or required, this is to be carried out using a suspension of magnetic particles in a suitable fluid. The dry powder method is not acceptable. Where current flow methods are used for magnetisation, particular care is to be taken to avoid damaging finished machined surfaces by contact burns from the prods.

1.7.8 Where required, magnetic particle or liquid penetrant testing is to be carried out by the manufacturer whenever appropriate and also when the castings are in the finished condition. The tests are to be made in the presence of the Surveyor unless otherwise specially agreed. The castings are to be examined in the following areas:

(a) At all accessible fillets and changes of section.
(b) At positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging.
(c) In way of fabrication weld preparations.
(d) At other positions agreed with the Surveyor to include areas which may be subjected to high stress in service.

Acceptance standards are to be to the satisfaction of the Surveyor.

1.7.9 Where required by subsequent Sections or by the agreed specification, ultrasonic examination is to be carried out by the manufacturer, but Surveyors may request to be present in order to verify that the examination is carried out in accordance with the agreed procedure. This examination is to be carried out in the following areas:

(a) At positions which may be subjected to high stresses in service, as agreed with the Surveyor.
(b) In way of fabrication weld preparations.
(c) At positions where experience shows that significant internal defects may occur: these are to be agreed between the manufacturer and the Surveyor.
(d) At positions where subsequent machining may expose filamentary shrinkage or other defects (e.g. bolt holes, bearing bores).

1.7.10 Radiographic examination is to be carried out by the manufacturer in areas generally as indicated for ultrasonic examination in 1.7.9. All radiographs are to be submitted to the Surveyor for examination and acceptance. The radiographic technique and acceptance standards are to be to the satisfaction of the Surveyor and in accordance with any requirements of the approved specification.

1.7.11 In the event of any casting proving to be defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.8 Pressure testing

1.8.1 Where required by the relevant Rules, castings are to be pressure tested in the final machined condition before final acceptance. These tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

1.9 Rectification of defective castings

1.9.1 When unacceptable defects are found in a casting, these are to be removed by machining or chipping. Flame-scarfing or arc-air gouging may also be used provided that pre-heating is employed when necessary and that the surfaces of the resulting excavation are subsequently ground smooth. Complete elimination of the defective material is to be proven by adequate non-destructive testing. Shallow grooves or excavations resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding. Complete elimination of the defective material is to be verified by magnetic particle or liquid penetrant testing. Small surface irregularities sealed by welding are to be treated as weld repairs.

1.9.2 Where flame scarfing or arc-air gouging is used, the requirements detailed in 1.2.2 are to apply.

1.9.3 Grinding wheels for use on austenitic stainless steels are to be of an iron-free type and shall have been used only on stainless steels.

1.9.4 All proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to satisfy himself that the number, position and size of the defects are such that the casting can be effectively repaired.

1.9.5 A statement and/or sketch detailing the extent and position of all weld repairs is to be prepared by the manufacturer. Copies of these sketches are to be submitted to LR, and copies are to be attached to the certificates for the castings.

1.9.6 Where it has been agreed that the casting can be repaired, the work is to be carried out by an approved welder and in accordance with an approved welding procedure which includes the features referred to in 1.9.6 to 1.9.13.

1.9.7 Where the weld repair of defects is required, a grain refining heat treatment is to be given to the whole casting prior to carrying out weld repairs unless agreed otherwise with the Surveyor. Grain refining heat treatment requires heating above the upper critical temperature.

1.9.8 Any excavations are to be of suitable shape to allow good access for welding and, after final preparation for welding, are to be re-examined by suitable non-destructive testing methods to ensure that all defective material has been eliminated.

1.9.9 All castings in alloy steels other than austenitic and duplex stainless steels are to be suitably preheated prior to welding. Castings in carbon-manganese steels may also be required to be preheated, depending on their chemical composition, the dimensions, configuration and positions of the weld repairs.

1.9.10 Welding is to be done under cover, in positions free from draughts and adverse weather conditions, by qualified welders with adequate supervision. As far as possible, all welding is to be carried out in the downhand (flat) position.

1.9.11 The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. The use of low hydrogen type welding consumables is preferred. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in 1.9.12, and the results of these tests are to be presented to the Surveyor.

1.9.12 After welding is completed, the castings are to be given the heat treatment specified in Sections 2 to 9, or a stress relieving heat treatment at a temperature of not less than 550°C. The type of heat treatment required will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs.

1.9.13 Special consideration may be given to a local stress relieving heat treatment where both the repaired area is small and machining of the casting has reached an advanced stage but prior agreement is to be obtained from LR (Materials and NDE Department). The welding procedure is to be such that residual stresses are minimized.

1.9.14 On completion of heat treatment, the weld repairs and adjacent material are to be ground smooth and examined by magnetic particle, or liquid penetrant testing, ultrasonic or radiographic examination. The Surveyor is to attend at these inspections, to witness the results of magnetic particle or liquid penetrant examination and to examine any radiographs. Satisfactory results are to be obtained from all forms of non-destructive testing used.

1.9.15 Where no weld repairs have to be made on a casting, the manufacturer is to provide the Surveyor with a statement that this is the case.

1.9.16 The foundry is to maintain full records detailing the weld procedure, heat treatment and the extent and location of repairs made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.9.17 For rectification of defective steel castings for crankshafts, *see* 4.7.

1.10 Identification of castings

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities to trace the castings when required.

1.10.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:
(a) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of Surveyor responsible for inspection.
(d) Test pressure, where applicable.
(e) Date of final inspection.

1.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.11 Certification

1.11.1 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:
(a) Purchaser's name and order number.
(b) Description of castings and steel quality.
(c) Identification number.
(d) Steel making process, cast number, chemical analysis of ladle samples and, in the case of the Special grade (*see* Section 2), the chemical analysis of the product or test bar.
(e) General details of heat treatment including the temperature and time at temperature.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.2 Where applicable, the manufacturer is to provide a signed statement regarding non-destructive testing as required by 1.7.6 together with a statement and/or sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.5 or the statement detailed in 1.9.15.

■ *Section 2* Castings for ship and other structural applications

2.1 Scope

2.1.1 The requirements for carbon-manganese steel castings, intended for ship and other structural applications where the design and acceptance tests are related to mechanical properties at ambient temperature, are given in this Section.

2.1.2 Provision is made for two quality grades, Normal and Special.

2.1.3 Where it is proposed to use carbon-manganese steels of higher specified minimum tensile strength than required by 2.4.3, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

2.2 Chemical composition

2.2.1 The chemical composition of ladle samples is to comply with Table 4.2.1.

Table 4.2.1 Chemical composition

Quality grade	Normal	Special (*see* Note 3)
Carbon	0,23% max.	0,23% max.
Silicon	0,60% max.	0,60% max.
Manganese	0,70–1,60%	0,70–1,60%
Sulphur	0,040% max.	0,035% max.
Phosphorus	0,040% max.	0,035% max.
Aluminium – (acid soluble)	—	0,015–0,080% (*see* Notes 1 and 2)
Residual elements:		
Copper	0,30% max.	0,30% max.
Chromium	0,30% max.	0,30% max.
Nickel	0,40% max.	0,40% max.
Molybdenum	0,15% max.	0,15% max.
Total	0,80% max.	0,80% max.

NOTES
1. The total aluminium content may be determined instead of the acid soluble content, in which case the total aluminium content is to be 0,020–0,10%.
2. Grain refining elements other than aluminium may be used subject to special agreement with LR.
3. For the Special grade, the nitrogen content is to be determined.

2.2.2 For the Special grade, the product of the aluminium and nitrogen contents is to comply with the following formula:

$$(\%\ Al_{acid\ sol} \times \%\ N)\ 10^5 \leq 60$$

2.2.3 For the Special grade, a check chemical analysis on the product or a test bar is mandatory. The check analysis on the product or test bar is to comply with the requirements of Table 4.2.1.

2.3 Heat treatment

2.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalized; or
(c) normalized and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

2.3.2 For larger castings where a coarse of microstructure may be present in heavier thickness, a double austenising heat treatment may be required to ensure adequate grain refinement. A coarse microstructure will be indicated by an increased attenuation of approxiamtely 30 dB/m at 2 MHz during ultrasonic examination.

2.3.3 Following weld repair and or the attachment of handling brackets, all castings are to be subject to post weld heat treatment at a temperature of not less than 550°C before delivery.

2.4 Mechanical tests

2.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

2.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. These are to be integrally cast at locations as widely separated as possible.

2.4.3 The results of these tests are to comply with the following requirements:

Yield stress	200 N/mm^2 min.
Tensile strength	400 N/mm^2 min.
Elongation on $5{,}65\sqrt{S_o}$	25% min.
Reduction of area	40% min.

2.4.4 A set of three Charpy V-notch impact test specimens is to be provided with each casting in the Special grade. These may be taken from a small extension of the thickest part of the casting or from a block cast integrally with the casting and having dimensions representative of the largest section thickness of the casting. These are to be tested in accordance with Chapter 2 and are to have an average energy of not less than 27J at 0°C.

2.5 Non-destructive examination

2.5.1 Castings used in ship construction for the sternframe, rudder and propeller shaft supports are to be examined by ultrasonic and magnetic particle methods in accordance with 1.7. The type and extent of non-destructive examination of castings for other structural applications are to be specially agreed by the Surveyor.

■ *Section 3* **Castings for machinery construction**

3.1 Scope

3.1.1 This Section gives the material requirements for carbon-manganese steel castings intended for use in machinery construction and which are not within the scope of Sections 4 to 7.

3.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 3.2.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

3.1.3 The manufacture or repair of cast steel connecting rods is not permitted, except where the manufacturing and quality control procedures have been approved by LR. For approval purposes, tests are to be carried out at the place of manufacture using the proposed process to demonstrate that the castings are sound. Tests are to be carried out to confirm that the appropriate mechanical properties are attained within the casting, including areas where weld repairs have been performed. Any changes to manufacturing, repair and quality control procedures are to be submitted to LR for approval, *see also* Ch 1,2.2.

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples is to comply with the following limits, except as specified in 3.2.2:

Carbon	0,40% max.
Silicon	0,60% max.
Manganese	0,50—1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

3.2.2 Castings which are intended for parts of a welded fabrication are to be of weldable quality with a carbon content generally not exceeding 0,23 per cent.

3.2.3 Proposals to use steels with higher carbon content, or alloy steels, for welded construction will be subject to special consideration.

3.3 Heat treatment

3.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalized; or
(c) normalized and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

3.3.2 Engine bedplate castings, turbine castings and any other castings where dimensional stability and freedom from internal stresses are important, are to be given a stress relief heat treatment. This is to be at a temperature not lower than 550°C, followed by furnace cooling to 300°C or lower. Alternatively, full annealing may be used provided that the castings are furnace cooled to 300°C or lower.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

3.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. The test samples are to be integrally cast at locations as widely separated as possible.

3.4.3 Table 4.3.1 gives the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate levels of minimum tensile strength may be specified, in which case minimum values for yield stress, elongation and reduction of area may be obtained by interpolation.

Table 4.3.1 Mechanical properties for acceptance purposes: carbon and carbon-manganese steel castings for machinery construction

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum
400–550	200	25	40
440–590	220	22	30
480–630	240	20	27
520–670	260	18	25
560–710	300	15	20
600–750	320	13	20

3.4.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.3.1.

3.4.5 The results of all tensile tests are to comply with the requirements of Table 4.3.1 appropriate to the specified minimum tensile strength.

3.4.6 For alloy steel castings and carbon-manganese steel castings containing more than 0,40 per cent carbon, the results of all mechanical tests are to comply with an approved specification.

3.4.7 When a casting, or a batch of castings, has failed to meet the mechanical test requirements, it may be re-heat treated and re-submitted for acceptance tests but this may not be carried out more than twice, *see* Ch 1,4.6.

3.5 Non-destructive examination

3.5.1 All piston crowns and cylinder covers are to be examined by ultrasonic testing. In addition, where these castings are intended for engines having a bore size larger than 400 mm, they are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.2 Engine bedplate castings are to be examined by ultrasonic and magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.3 Turbine castings are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7. In addition, an ultrasonic or radiographic examination is to be made in way of fabrication weld preparations.

3.5.4 Other castings are to be examined by non-destructive methods where specified.

■ *Section 4* Castings for crankshafts

4.1 Scope

4.1.1 This Section gives the requirements for carbon and carbon-manganese steel castings for semi-built crankshafts.

4.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 4.3.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For alloy steels, the specified minimum tensile strength is not to exceed 700 N/mm^2.

4.2 Manufacture

4.2.1 The method of producing combined web and pin castings is to be approved. For this purpose, tests to demonstrate the soundness of the casting and the properties at important locations may be required.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with the following limits:

Carbon	0,40% max. (*but see* 4.7.5(c))
Silicon	0,60% max.
Manganese	0,50–1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

4.4 Heat treatment

4.4.1 Castings are to be supplied either:

(a) fully annealed and cooled in the furnace to a temperature of 300°C or lower; or

(b) normalized and tempered at a temperature of not less than 550°C, and cooled in the furnace to a temperature of 300°C or lower.

4.5 Mechanical tests

4.5.1 Proposals for the number of tests and the location of test material on the casting are to be submitted by the manufacturer.

4.5.2 Not less than one tensile test and three impact tests are to be made on material representing each casting. The impact tests are to be carried out at ambient temperature.

4.5.3 Table 4.4.1 gives the minimum requirements for yield stress and elongation corresponding to different strength levels, and it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2 to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 4.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel castings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests average energy J minimum (*see* Note)
400–550	200	28	45	32
440–590	220	26	45	28
480–630	240	24	40	25
520–670	260	22	40	20
550–700	275	20	35	18

NOTE
Impact tests are to be made at ambient temperature.

4.5.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.4.1.

4.5.5 The results of all tests are to comply with the requirements of Table 4.4.1 appropriate to the specified minimum tensile strength. For the impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

4.6 Non-destructive examination

4.6.1 Magnetic particle examination is to be carried out over all surfaces in accordance with Fig. 4.4.1.

4.6.2 Each casting is to be examined by ultrasonic testing, and the extent of examination and defect acceptance criteria, using the DGS (Distance Gain Size) technique, are to be as shown in Fig. 4.4.2. Alternative ultrasonic procedures may be submitted for approval.

4.7 Rectification of defective castings

4.7.1 The requirements of 1.9 apply, except where amended by this Section.

4.7.2 Where castings have shallow surface defects, consideration is first to be given to removing such defects by grinding and blending or by machining the surface where there is excess metal on the Rule dimension.

4.7.3 Welded repairs are to be undertaken only when the repairs are considered to be necessary and are approved by the Surveyor.

4.7.4 Subject to prior agreement and submission of the detailed welding procedure for approval by LR, weld repairs may be carried out prior to the final austenitizing heat treatment.

4.7.5 Approval for weld repairs will not be given in the following circumstances:

(a) For the rectification of repetitive defects caused by improper foundry technique or practice.

(b) For the building up by welding of surfaces or large shallow depressions.

(c) Where the carbon content of the steel exceeds 0,30 per cent.

(d) Where the carbon equivalent of the steel, given by $C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$ exceeds 0,65 per cent.

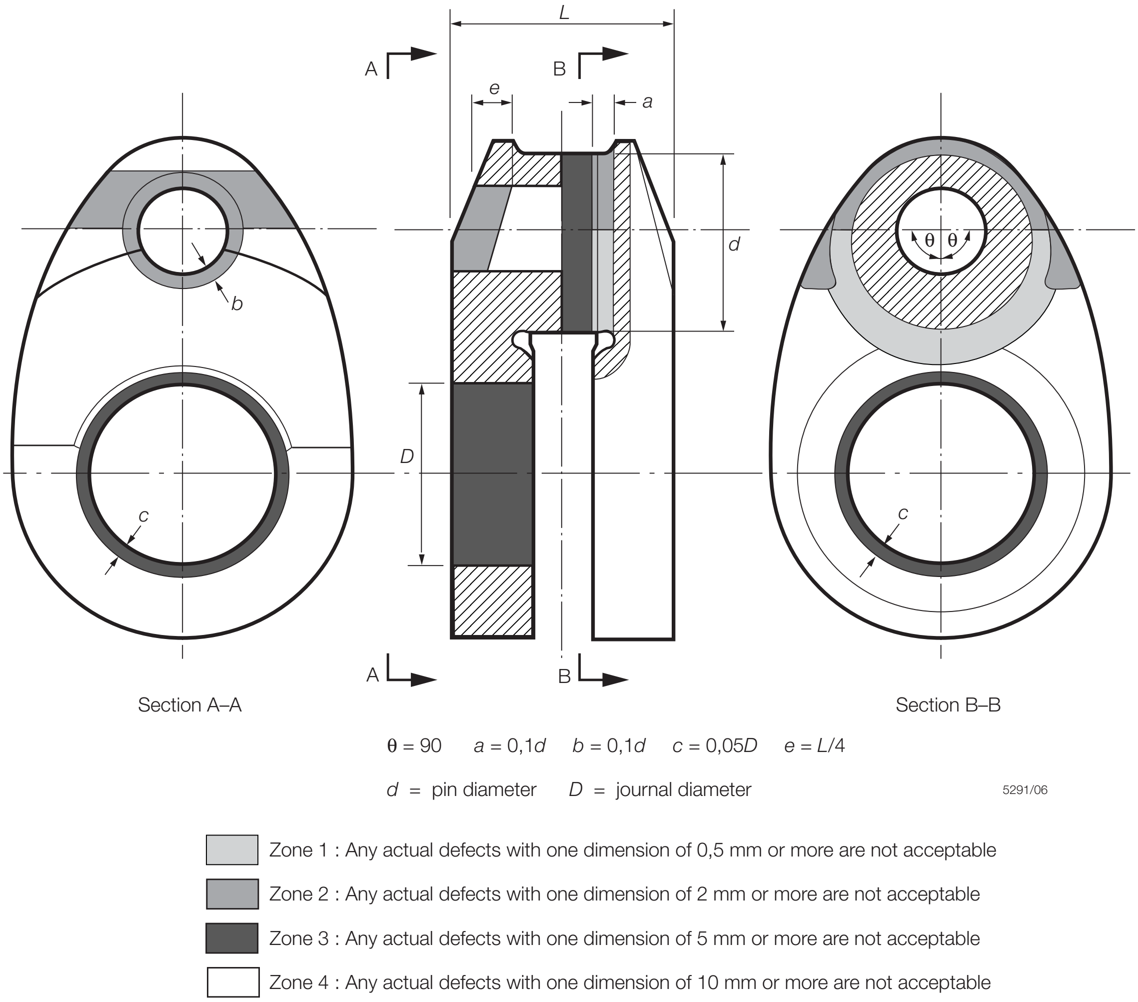


Fig. 4.4.1 Magnetic particle inspection acceptance levels

4.7.6 Provided that the Surveyors are satisfied that repairs by welding are justified, they may also authorise repairs to the surfaces of crankwebs, following the final austenitizing heat treatment, within the following limits:

(a) In general, the volume of the largest groove which is to be welded is not to exceed 3,2t cm^3, where t is the web axial thickness, in cm. The total volume of all grooves which are to be welded is not to exceed 9,6t cm^3 per crankweb.

(b) The welds do not extend within the cross-hatched zones marked on Fig. 4.4.3 for semi-built crank throws.

(c) Larger repairs on balance weights may be permitted at the discretion of the Surveyor, provided that such repairs are wholly contained within the balance weight and do not affect the strength of the crankweb.

4.7.7 Subsequent to the final austenitizing heat treatment, weld repairs may also be authorized in the surface of the bore for the journal (or pin) within the following limits:

(a) In general, the welds are to be not less than 125 mm apart.

(b) The welds are not to be located within circumferential bands of $\frac{t}{5}$ from the edges of the bores, nor at any position within the inner 120° arc of the bores, as cross-hatched on Fig. 4.4.3.

(c) The volume of the largest weld is to be not more than 1,1t cm^3, where t is the web axial thickness at the bore, in cm, and not more than three welds are to be made in any one bore surface.

4.7.8 After all defective material has been removed from a region, and this has been proven in the presence of the Surveyor by magnetic particle inspection or other suitable method, the excavation is to be suitably shaped to allow good access for welding.

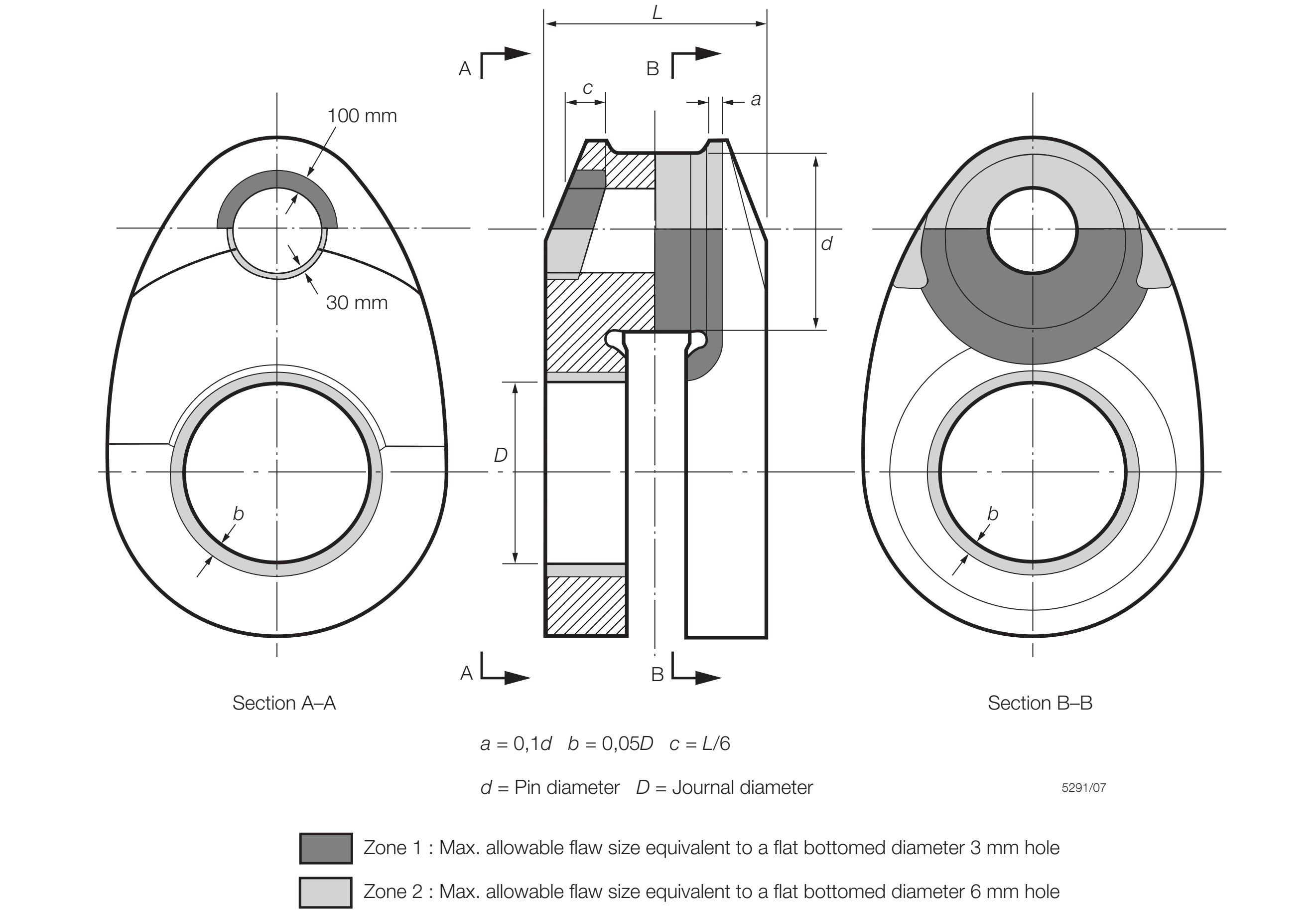


Fig. 4.4.2 Ultrasonic examination acceptance levels

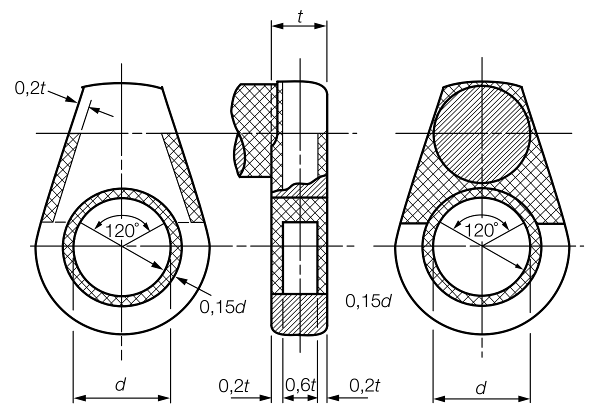


Fig. 4.4.3
Areas of semi-built crank throws to which weld repairs are not permitted

4.7.9 At the discretion of the Surveyor, the size of a groove may be increased beyond the limiting sizes given in 4.7.6 or 4.7.7, if the removal of further metal will facilitate welding.

4.7.10 Weld repairs are to be carried out by approved welders using approved procedures. The welds are to be made by an electric arc process using low hydrogen type consumables which will produce a deposited metal that is not inferior in properties to the parent metal.

4.7.11 All castings are to be given a preliminary refining heat treatment prior to the commencement of weld repairs. Before welding, the material is to be preheated in accordance with the qualified procedure. Where possible, preheating is to be carried out in a furnace. The preheat temperature is to be maintained until welding is completed, and preferably until the casting is charged to the furnace for post-weld heat treatment.

4.7.12 Where weld repairs are carried out after the final austenitizing heat treatments, a post-weld stress relieving heat treatment is to be applied at a temperature of not less than 600ºC, *see also* 1.5.2.

4.7.13 Welds are to be dressed smooth by grinding, and proven by magnetic particle and, where appropriate, ultrasonic inspection. The surfaces of the welds and adjacent parent steel are to be free from harmful defects.

Section 5
Castings for propellers

5.1 Scope

5.1.1 This Section gives the requirements for steel castings for one-piece propellers and separately cast blades and hubs for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers, azipods and azimuth thrusters. The requirements for copper alloy propellers, blades and hubs are given in Ch 9,1.

5.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and Ch 4,1 as well as the requirements of this Section.

5.1.3 Full details of the manufacturer's specification are to be submitted for approval. These should include the chemical composition, heat treatment, mechanical properties, microstructure and repair procedures.

5.1.4 Special requirements are given for castings which are intended for ice service in Table 4.5.2.

5.2 Chemical composition

5.2.1 The chemical composition of ladle samples is to comply with the approved specification, *see* 5.1.3.

5.2.2 Typical cast steel propeller alloys are given in Table 4.5.1.

5.3 Heat treatment

5.3.1 Martensitic stainless steel castings are to be austenitized, quenched and tempered in accordance with the approved specification, *see* 5.1.3.

5.3.2 Austenitic stainless steel castings are to be solution treated in accordance with the approved specification, *see* 5.1.3.

5.4 Mechanical tests

5.4.1 The test material is to be cast integral with the boss of propeller castings, or with the flange of separately cast propeller blades. Alternatively, the test material may be attached on blades in an area between 0,5 and 0,6*R*, where *R* is the radius of the propeller.

5.4.2 The test material is not to be removed from the casting until final heat treatment has been carried out. Removal is to be by non-thermal procedures.

5.4.3 At least one tensile test and for the martensitic stainless steel grades one set of three Charpy V-notch impact tests are to be made on material representing each casting. The results are to comply with the requirements of Table 4.5.2 or the approved specification.

Table 4.5.1 Typical chemical composition for steel propeller castings

Alloy type	C Max. (%)	Mn Max. (%)	Cr (%)	Mo Max. (%) (*see* Note)	Ni (%)
Martensitic (12Cr 1Ni)	0,15	2,0	11,5–17,0	0,5	Max. 2,0
Martensitic (13Cr 4Ni)	0,06	2,0	11,5–17,0	1,0	3,5–5,0
Martensitic (16Cr 5Ni)	0,06	2,0	15,0–17,5	1,5	3,5–6,0
Austenitic (19Cr 11Ni)	0,12	1,6	16,0–21,0	4,0	8,0–13,0

NOTE
Minimum values are to be in accordance with the agreed specification or recognized National or International Standards.

Table 4.5.2 Typical mechanical properties for steel propeller castings

Alloy type	Yield stress or, 0,2% proof stress minimum, N/mm^2	Tensile strength minimum N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests J minimum (*see* Notes 1 and 2)
Martensitic (12Cr 1Ni)	440	590	15	30	20
Martensitic (13Cr 4Ni)	550	750	15	35	30
Martensitic (16Cr 5Ni)	540	760	15	35	30
Austenitic (19Cr 11Ni)	180 (*see* Note 3)	440	30	40	—

NOTES
1. When a general service notation Ice Class 1AS, 1A, 1B or 1C is required, the tests are to be made at –10°C.
2. For general service or where the notation Ice Class 1D is required, the tests are to be made at 0°C.
3. $R_{p1,0}$ value is 205 N/mm^2.

5.4.4 As an alternative to 5.4.3, where a number of small propeller castings of about the same size, and less than 1 m in diameter, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one set of mechanical tests is to be provided for each multiple of five castings in the batch.

5.5 Non-destructive examination

5.5.1 On completion of machining and grinding, the whole surface of each casting is to be examined in accordance with Ch 9,1.8.

5.5.2 When appropriate, magnetic particle inspection may be used in lieu of liquid penetrant testing.

5.6 Rectification of defective castings

5.6.1 The rectification of defective castings is to be undertaken in accordance with 1.9 and the following paragraphs.

5.6.2 Removal of defective material is to be by mechanical means, e.g. by grinding, chipping or milling. The resultant grooves are to be blended into the surrounding surface so as to avoid any sharp contours.

5.6.3 Grinding in severity zone A may be carried out to an extent that maintains the blade thickness. Repair by welding is generally not permitted in zone A and will only be allowed after special consideration.

5.6.4 Defects in severity zone B that are not deeper than $t/40$ mm (t is the minimum local thickness according to the Rules) or 2 mm, whichever is the greater, are to be removed by grinding. Those defects that are deeper may be repaired by welding subject to prior approval of the Surveyor.

5.6.5 Repair welding is generally permitted in severity zone C.

5.6.6 Welds having an area of less than 5 cm^2 are to be avoided. The maximum surface area of repairs is to be in accordance with Table 9.1.4 in Chapter 9.

5.6.7 Welding is to be in accordance with the approved specification, *see* 5.1.3.

5.6.8 After weld repair, the propeller or blade is to be heat treated in such fashion as will minimize the residual stresses. For martensitic stainless steels, this will involve full heat treatment as specified in the approved specification.

5.6.9 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

5.7 Identification

5.7.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:

(a) Identification mark which will enable the full history of the item to be traced.
(b) Type of steel, this should include or allow identification of the chromium and nickel contents.
(c) LR or Lloyd's Register and the abbreviated name of Lloyd's Register's local office.
(d) Personal stamp of Surveyor responsible for the final inspection.
(e) LR certificate number.
(f) Skew angle, if in excess of 25°.
(g) Ice class symbol, where applicable.
(h) Date of final inspection.

5.8 Certification

5.8.1 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting:

(a) Purchaser’s name and order number.
(b) Description of casting with drawing number.
(c) Type of steel, including designation and chemical composition.
(d) Diameter, number of blades, pitch, direction of turning.
(e) Cast identification number.
(f) Details of heat treatment, where applicable.
(g) Skew angle, if in excess of 25°.
(h) Final mass.
(j) Results of mechanical tests.
(k) Vessel identification, where known.

■ *Section 6*
Castings for boilers, pressure vessels and piping systems

6.1 Scope

6.1.1 This Section gives the requirements for carbon-manganese and alloy steel castings for boilers, pressure vessels and piping systems for use at temperatures not lower than 0°C.

6.1.2 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases, the specified minimum tensile strength is not to exceed 600 N/mm^2.

6.1.3 Castings which comply with these requirements are acceptable for liquefied gas piping systems where the design temperature is not lower than 0°C. Where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required, the castings are to comply with the requirements of Section 7 or 8.

6.2 Chemical composition

6.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.6.1.

6.3 Heat treatment

6.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalized; or
(c) normalized and tempered; or
(d) quenched and tempered.

6.4 Mechanical tests

6.4.1 A tensile test is to be made on material representing each casting, unless a batch testing procedure has been agreed, *see* 1.6.

6.4.2 The tensile test is to be carried out at ambient temperature, and unless agreed otherwise with the Surveyor, the results are to comply with the requirements of Table 4.6.2.

6.4.3 Where it is proposed to use a carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and reduction of area may be obtained by interpolation.

6.4.4 Carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm², but not exceeding 520 N/mm², may be accepted provided that details of the proposed specification are submitted for approval.

Table 4.6.1 Chemical composition of steel castings for boilers, pressure vessels and piping systems

Type of steel	Chemical composition %										
	C max.	Si max.	Mn	S max.	P max.	Residual elements					
Carbon-manganese	0,25	0,60	0,50-1,20	0,040	0,040	Cr 0,30 max. Mo 0,15 max. Cu 0,30 max. Ni 0,40 max. Total 0,80 max.					
						Cr	Mo	V	Residual elements Cr	Cu	Ni
$^1/_2$ Mo	0,20	0,60	0,50–1,00	0,040	0,040	—	0,45-0,65	—	0,30 max.	0,30 max.	0,40 max.
1 Cr $^1/_2$ Mo	0,20	0,60	0,50-0,80	0,040	0,040	1,00-1,50	0,45-0,65	—	—	0,30 max.	0,40 max.
2 $^1/_4$ Cr1 Mo	0,18	0,60	0,40-0,70	0,040	0,040	2,00-2,75	0,90-1,20	—	—	0,30 max.	0,40 max.
$^1/_2$ Cr $^1/_2$ Mo $^1/_4$ V	0,10–0,15	0,45	0,40-0,70	0,030	0,030	0,30-0,50	0,40-0,60	0,22-0,30	—	0,30 max.	0,30 max.

Table 4.6.2 Mechanical properties for acceptance purposes: steel castings for boilers, pressure vessels and piping systems

Type of steel	Yield stress minimum N/mm²	Tensile strength N/mm²	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum
Carbon-manganese	275	485-655	22	25
$^1/_2$Mo	260	460-590	18	30
1Cr$^1/_2$Mo	280	480-630	17	20
2$^1/_4$ Cr1 Mo	325	540-630	17	20
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	295	510-660	17	20

Table 4.6.3 Mechanical properties for design purposes (*see* 6.6.1)

Type of steel	Nominal minimum lower yield or 0,2% proof stress N/mm²										
	Temperature °C										
	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese	225	214	201	186	163	156	152	—	—	—	—
$^{1}/_{2}$Mo	242	236	226	207	186	175	169	158	145	136	126
1Cr$^{1}/_{2}$Mo	240	—	212	—	196	—	184	—	160	—	117
2$^{1}/_{4}$Cr1 Mo	323	312	305	296	290	280	273	258	240	211	180
$^{1}/_{2}$Cr$^{1}/_{2}$Mo$^{1}/_{4}$V	264	—	244	—	230	—	214	—	194	—	144

6.5 Non-destructive examination

6.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.6 to 1.7.10 and additionally as agreed between the manufacturer, purchaser and Surveyor.

6.6 Mechanical properties for design purposes

6.6.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 100°C and higher are given in Table 4.6.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 4.6.3.

Table 4.6.4 Mechanical properties for design purposes (*see* 6.6.3)**: estimated average stresses to rupture in 100,000 hours (N/mm²)**

Temperature °C	Type of steel			
	$^{1}/_{2}$Mo	1Cr$^{1}/_{2}$Mo	2$^{1}/_{4}$Cr1Mo	$^{1}/_{2}$Cr$^{1}/_{2}$Mo$^{1}/_{4}$V
430	308	—	—	—
440	276	—	—	—
450	245	—	222	277
460	212	—	199	237
470	174	236	177	206
480	133	186	156	181
490	103	148	139	159
500	84	120	124	140
510	71	100	111	124
520	60	84	99	109
530	—	70	—	96
540	—	58	—	85
550	—	—	—	75
560	—	—	—	66

6.6.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each casting or each batch of castings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

6.6.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 4.6.4 and may be used for design purposes.

■ *Section 7* Ferritic steel castings for low temperature service

7.1 Scope

7.1.1 This Section gives the requirements for castings in carbon-manganese and nickel alloy steels intended for use in liquefied gas piping systems where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required.

7.1.2 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.7.1. Carbon-manganese steels are to be made by fine grain practice.

7.3 Heat treatment

7.3.1 Castings are to be supplied:
(a) normalized; or
(b) normalized and tempered; or
(c) quenched and tempered.

Table 4.7.1 Chemical composition of ferritic steel castings for low temperature service

Type of steel	Chemical composition %						
	C max.	Si max.	Mn	S max.	P max.	Ni	Residual elements max.
Carbon-manganese	0,25	0,60	0,70-1,60	0,030	0,030	0,80 max.	Cr 0,25 Cu 0,30 Mo 0,15 V 0,03 Total 0,60
$2^1/_4$Ni	0,25	0,60	0,50-0,80	0,025	0,030	2,00-3,00	
$3^1/_2$Ni	0,15	0,60	0,50-0,80	0,020	0,025	3,00-4,00	

Table 4.7.2 Mechanical properties for acceptance purposes: ferritic steel castings for low temperature service

Type of steel	Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction or area % minimum	Charpy V-notch impact test	
						Test temperature °C	Average energy J minimum
Carbon-manganese	400 430 460	200 215 230	400-550 430-580 460-610	25 23 22	40 35 30	–60 (*see* Note)	27
$2^1/_4$Ni	490	275	490-640	20	35	–70	34
$3^1/_2$Ni	490	275	490-640	20	35	–95	34

NOTE
The test temperature for carbon-manganese steels may be 5°C below the design temperature if the latter is above –55°C, with a maximum test temperature of –20°C.

7.4 Mechanical tests

7.4.1 One tensile test and one set of three Charpy V-notch impact test specimens are to be prepared from material representing each casting or batch of castings.

7.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the appropriate requirements given in Table 4.7.2.

7.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.7.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedure.

7.5 Non-destructive examination

7.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.6 to 1.7.10 and additionally agreed between the manufacturer, purchaser and Surveyor.

■ *Section 8* Austenitic stainless steel castings

8.1 Scope

8.1.1 This Section gives the requirements for castings in austenitic stainless steels for piping systems in ships for liquefied gases where the design temperature is not lower than –165°C, and in bulk chemical tankers.

8.1.2 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 4.8.1.

Table 4.8.1 Chemical composition of austenitic stainless steel castings

Type of steel	Chemical composition %								
	C max.	Si	Mn	S	P	Cr	Mo	Ni	Others
304L	0,03	0,20-1,5	0,50-2,0	0,040 max.		17,0-21,0	—	8,0–12,0	—
304	0,08						—	8,0–12,0	—
316L	0,03						2,0–3,0	9,0–13,0	—
316	0,08						2,0–3,0	9,0–13,0	—
317	0,08						3,0–4,0	9,0–12,0	—
347 (*see* Note)	0,06						—	9,0–12,0	Nb ≥ 8 x C ≤ 0,90

NOTE
When guaranteed impact values at low temperature are not required, the maximum carbon content may be 0,08% and the maximum niobium may be 1,00%.

Table 4.8.2 Mechanical properties for acceptance purposes: austenitic stainless steel castings

Type of steel	Tensile strength N/mm^2 minimum	1,0% proof stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
304L	430	215	26	40	–196	41
304	480	220				
316L	430	215	26	40	–196	41
317	480	240				
347	480	215	22	35	–196	41

8.3 Heat treatment

8.3.1 All castings are to be solution treated at a temperature of not less than 1000°C and cooled rapidly in air, oil or water.

8.4 Mechanical tests

8.4.1 One tensile test specimen is to be prepared from material representing each casting or batch of castings. In addition, where the castings are intended for liquefied gas applications, where the design temperature is lower than –55°C, one set of three Charpy V-notch impact test specimens is to be prepared.

8.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the requirements given in Table 4.8.2.

8.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.8.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

8.5 Intergranular corrosion tests

8.5.1 Where corrosive conditions are anticipated in service, intergranular corrosion tests are required on castings in grades 304, 316 and 317. Such tests may not be required for grades 304L, 316L and 347.

8.5.2 Where an intergranular corrosion test is specified, it is to be carried out in accordance with the procedure given in Ch 2,8.1.

8.6 Non-destructive examination

8.6.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.6 to 1.7.10 and additionally agreed between the manufacturer, purchaser and Surveyor.

■ *Section 9* Steel castings for container corner fittings

9.1 General

9.1.1 This Section gives the requirements for cast steel corner fittings used in the fabrication of freight and tank containers. The fittings are also to comply with the requirements of the latest edition of International Standard ISO 1161.

9.1.2 The castings are to be made in foundries approved by LR. These foundries are also to be specially approved for the manufacture of container corner castings. In order to comply with these requirements, the manufacturer is required to verify that the casting soundness, mechanical properties, weldability and dimensional tolerances required by this Section and the manufacturing specification are met.

9.1.3 Castings may be released on the basis of an LR survey or, alternatively, the manufacturer may be approved by means of a Quality Assurance Scheme as detailed in Ch 1,2.

9.2 Chemical composition

9.2.1 Chemical analysis is to be carried out on each cast.

9.2.2 The chemical composition of the ladle samples is to comply with the limits given in Table 4.9.1.

9.2.3 The carbon equivalent:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \ (\%)$$

must not exceed 0,45 per cent.

9.3 Heat treatment

9.3.1 Castings are to be supplied either:

(a) normalized; or

(b) water or oil quenched and tempered at a temperature of not less than 550°C.

9.4 Mechanical tests

9.4.1 At least one tensile test is to be made on each batch of castings, using separately cast test bars which are to be from the same cast and heat treatment lot as the castings they represent.

9.4.2 The results of the tensile tests are to comply with the following:

Yield stress	220 N/mm^2 min.
Tensile strength	430–600 N/mm^2
Elongation on $\sqrt{S_o}$	25% min.
Reduction of area	40% min.

9.4.3 Impact tests are not required on all casts but may be required on a random basis at the discretion of the Surveyor.

9.4.4 When required, the impact test specimens are to be tested in accordance with Ch 1,4.5 and Ch 2,3.2. In general, tests are to be made at a temperature of –20°C and the minimum average energy obtained is to be 27J.

9.5 Non-destructive examination

9.5.1 Ultrasonic or radiographic testing is to be carried out, in accordance with 1.7.9 or 1.7.10 respectively, on at least one casting from each cast or from every 400 castings, whichever is the lesser.

9.6 Repair of defects

9.6.1 Minor defects may be removed by grinding provided that the allowable minus tolerance is not exceeded.

Table 4.9.1 Chemical composition of steel castings for container corner fittings

Chemical composition %										
C max.	Mn	Si max.	P max.	S max.	Cr max.	Ni max.	Cu max.	Mo max.	Al acid soluble min. (*See* Notes)	Cr + Ni + Cu + Mo max.
0,20	0,90 to 1,50	0,50	0,035	0,035	0,25	0,30	0,20	0,08	0,015	0,70

NOTES
1. The total aluminium content may be determined instead of the acid soluble content. In such cases, the total aluminium content is to be not less than 0,02%.
2. Aluminium may be replaced partly or totally by other grain refining elements as stated in the approved specification.

9.6.2 Defects which exceed the allowable minus tolerance may be removed by grinding or chipping followed by welding, provided the weld depth does not exceed 40 per cent of the wall thickness and that the following requirements are met:
(a) welding is not to be carried out in the as-cast condition; the grain structure has to be refined by heat treatment,
(b) the casting is to be preheated to 80–100°C,
(c) welding is to be performed only by qualified welders in accordance with a qualified welding procedure,
(d) all welded castings are to be post-weld heat treated at a temperature not less than 550°C,
(e) the welded areas are to be ground or machined flush with the adjacent surface and inspected by magnetic particle or dye penetrant examination as appropriate.

9.7 Identification

9.7.1 Each casting is to be clearly marked by the manufacturer with at least the following:
(a) manufacturer's name or trade mark,
(b) cast number or identification number which will enable the full history of the casting to be traced.

9.7.2 Where the casting has been inspected and found acceptable it is to be marked with the Surveyor's personal stamp.

9.7.3 The markings may be stamped or cast on the inner surface of the casting.

9.8 Certification

9.8.1 For each consignment the manufacturer is to provide the Surveyor with a certificate or delivery note containing at least the following:
(a) Purchaser's name and order number.
(b) Grade of steel.
(c) Drawing and/or specification number.
(d) Cast number and chemical composition.
(e) Details of the heat treatment.
(f) Number and weight of the castings.
(g) Results of inspections and mechanical tests.

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel forgings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems. These requirements are also applicable to rolled slabs and billets used as a substitute for forgings and to rolled bars used for the manufacture (by machining operations only) of shafts, bolts, studs and other components of similar shape.

1.1.2 When required by the relevant Rules dealing with design and construction, forgings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, steel forgings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Normalised forgings with mass up to 1000 kg each and quenched and tempered forgings with mass up to 500 kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 tonnes for normalised forgings and 3 tonnes for quenched and tempered forgings, respectively.

1.1.5 A batch testing procedure may also be used for hot rolled bars, *see* 3.4.3.

1.1.6 Where small forgings are produced in large quantities, or where forgings of the same type are produced in regular quantities, alternative survey procedures in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Forgings are to be made at works which have been approved by Lloyd's Register (hereinafter referred to as LR). The steel used is to be manufactured in accordance with the requirements of Ch 3,1.3.

1.2.2 When forgings are made directly from ingots, or from blooms or billets forged from ingots, the ingots are to be cast in chill moulds with the larger cross-section uppermost and with efficient feeder heads.

1.2.3 Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

1.2.4 The forgings are to be gradually and uniformly hot worked and are to be formed as closely as possible to the finished shape and size. The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment.

1.2.5 For certain components, such as crankshafts, where grain flow is required in the most favourable direction having regard to the mode of stressing in service, the proposed method of manufacture may require special approval by LR. In such cases, tests may be required to demonstrate that a satisfactory structure and grain flow are obtained.

1.2.6 The reduction ratio (reduction of area expressed as a ratio) is to be calculated with reference to the average cross-sectional area of the ingot or continuously cast material, where appropriate. Where an ingot is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

1.2.7 For components forged directly from ingots or from forged blooms or billets, and in which the fibre deformation is mainly longitudinal, the reduction ratio is not to be less than 3:1.

1.2.8 For forgings made from rolled billets, or where fibre deformation has taken place in more than one direction, the reduction ratio is not to be less than 4:1.

1.2.9 Where rolled bars are used as a substitute for forgings and the requirements of 1.2.2 are not complied with, the reduction ratio is to be not less than 6:1.

1.2.10 Where the length of any section of a shaft forging is less than its diameter (e.g. a collar), the reduction ratio is to be not less than half that given in 1.2.7, 1.2.8 or 1.2.9 respectively.

1.2.11 Disc type forgings, such as gear wheels, are to be made by upsetting, and the thickness of any part of the disc is to be not more than one-half of the length of the billet from which it was formed, provided that this billet has received an initial forging reduction of not less than 1,5:1. Where the piece used has been cut directly from an ingot, or where the billet has received an initial reduction of less than 1,5:1, the thickness of any part of the disc is to be not more than one-third of the length of the original piece.

1.2.12 Rings and other types of hollow forgings are to be made from pieces cut from ingots or billets and which have been suitably punched, bored or trepanned prior to expanding or hollow forging. Alternatively, pieces from hollow cast ingots may be used. The wall thickness of the forging is to be not more than one-half of the thickness of the prepared hollow piece from which it was formed. Where this is not practicable, the forging procedure is to be such as to ensure that adequate work is given to the piece prior to punching, etc. This may be either longitudinal or upset working of not less than 2:1.

1.2.13 The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all flame cut surfaces may be required, *see* 4.2.4.

1.2.14 Where two or more forgings are joined by welding to form a composite component, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests may be required.

1.3 Quality

1.3.1 All forgings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.4 Chemical composition

1.4.1 All forgings are to be made from killed steels, and the chemical composition of ladle samples is to comply with the requirements detailed in subsequent Sections in this Chapter. Where general overall limits are specified, the chemical composition selected is to be appropriate for the type of steel, dimensions and required mechanical properties of the forgings being manufactured.

1.4.2 Except where otherwise specified, suitable grain refining elements such as aluminium, niobium or vanadium may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.4.3 For alloy steel forgings, the chemical composition of ladle samples is to generally comply with the following overall limits and the requirements of the approved specifications:

Carbon	0,45% max.
Silicon	0,45% max.
Manganese	0,30% min.
Sulphur	0,035% max.
Phosphorus	0,035% max.
Copper	0,30% max

And at least one of the following elements is to comply with the minimum content:

Chromium	0,40% min
Molybdenum	0,15% min
Nickel	0,40% min

The contents of all alloying elements and significant impurities detailed in the specification are to be reported.

1.4.4 Details of the proposed chemical composition for carbon-manganese steel forgings intended for welding and alloy steel forgings are to be submitted for approval.

1.5 Heat treatment

1.5.1 At an appropriate stage of manufacture, after completion of all hot working operations, forgings are to be suitably heat treated to refine the grain structure and to obtain the required mechanical properties. Acceptable heat treatment procedures are to be such as to avoid the formation of hair-line cracks and are detailed in Sections 2 to 9.

1.5.2 Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform. Alternative procedures are to be approved by LR, Materials and NDE Department.

1.5.3 Where forgings are to be quenched and tempered and cannot be hot worked close to size and shape, they are to be suitably rough machined or flame cut prior to being subjected to this treatment.

1.5.4 If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat treated.

1.5.5 If any straightening operation is performed after the final heat treatment, consideration should be given to a subsequent stress relieving heat treatment in order to avoid the possibility of harmful residual stresses.

1.5.6 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for approval. For the purposes of this approval, the manufacturer will be required to demonstrate by tests that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel.

1.5.7 Where induction hardening or nitriding is to be carried out after machining, forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

1.5.8 Where carburizing is to be carried out after machining, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalizing and tempering) to a condition suitable for subsequent machining and carburizing.

1.5.9 The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, thermocouple location, date, temperature and time at temperature. The records are to be presented to the Surveyor on request.

1.6 Test material

1.6.1 Test material, sufficient for the required tests and for possible re-test purposes, is to be provided with a cross-sectional area of not less than that part of the forging which it represents. This test material is to be integral with each forging, except in the case of small forgings which are batch tested, *see* 1.6.4.

1.6.2 Where a forging is subsequently divided into a number of components, all of which are heat treated together in the same furnace charge, for test purposes this may be regarded as one forging and the number of tests required is to be related to the total length and mass of the original multiple forging, *see* 2.4.2.

1.6.3 Except for components which are to be carburized, test material is not to be cut from a forging until the heat treatment detailed in Sections 2 to 9 has been completed. The testing procedure for components which are to be carburized is to be in accordance with the details given in Section 5.

1.6.4 Where a number of small forgings of about the same size are made from one cast and heat treated in the same furnace charge, batch testing procedures (*see* 1.1.4) may be adopted using one of the forgings for test purposes, or alternatively using separately forged test samples. These test samples are to have a forging reduction similar to that used for the forgings which they represent. They are to be properly identified and heat treated together with the forgings.

1.7 Mechanical tests

1.7.1 Specimens for mechanical tests are to be prepared as required by Sections 2 to 9.

1.7.2 Test specimens are normally to be cut with their axes mainly parallel (longitudinal test) or mainly tangential (tangential test) to the principal axial direction of each product.

1.7.3 Unless otherwise agreed, the longitudinal axis of the test specimens is to be positioned as follows:

(a) for thickness or diameter ≤ 50 mm, the axis is to be at the mid-thickness or the centre of the cross-section;

(b) for thickness or diameter > 50 mm, the axis is to be at one quarter thickness (mid-radius) or 30 mm, whichever is less, below any heat treated surface;

Test pieces shall be taken in such a way that no part of the gauge length is machined from material closer than 12,5 mm to any heat treated surface. For impact testing, this requirement is to apply to the complete test piece.

1.7.4 Tensile test specimens are to be machined to the dimensions detailed in Chapter 2. Where this is precluded by the dimensions of the forging, the test specimen is to be of the largest practicable cross-sectional area.

1.7.5 Impact test specimens are to be prepared in accordance with the requirements of Chapter 2.

1.7.6 The procedures used for the tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.7.7 Hardness tests, preferably of the Brinell type, are to be carried out when specified in subsequent Sections in this Chapter.

1.8 Visual and non-destructive examination

1.8.1 Before acceptance, all forgings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces and bores.

1.8.2 Forgings are to be examined in the condition for final delivery. Surfaces are to be clean and free from dirt, grease, paint, etc. Black forgings are to be suitably descaled by either shotblasting or flame descaling methods.

1.8.3 Visual examination may indicate areas which are to be examined by magnetic particle, dye penetrant or ultrasonic examination in addition to that indicated in 1.8.4.

1.8.4 When specified in subsequent Sections in this Chapter, or by an approved procedure for welding composite components, *see* 1.2.14, appropriate non-destructive examination is also to be carried out before acceptance. All such tests are to be carried out by competent operators using reliable and efficiently maintained equipment. The testing procedures used are to be agreed with the Surveyors.

1.8.5 Magnetic particle and liquid penetrant testing is to be carried out when the forgings are in the finished machined condition, *see also* Ch 1,2.3.5. Where current flow methods are used for magnetization, particular care is to be taken to avoid damaging machined surfaces by contact burns from the prods. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyor.

1.8.6 Acceptance standards for defects found by magnetic particle or liquid penetrant testing are to be to the satisfaction of the Surveyors and in accordance with any specific requirements of the approved plan.

1.8.7 Where required, ultrasonic examination is to be carried out after the forgings have been machined to a condition suitable for this type of examination and after the final heat treatment. Both radial and axial scanning are to be carried out where appropriate for the shape and the dimensions of the forgings being examined. Unless otherwise agreed, this examination is to be carried out by the manufacturer, although Surveyors may request to be present in order to verify that the examination is being carried out in accordance with the agreed procedure.

1.8.8 If the forging is supplied in the black condition for machining at a separate works, the manufacturer is to ensure that a suitable ultrasonic examination is carried out to verify the internal quality of the forging.

1.8.9 In the circumstance detailed in either 1.8.7 or 1.8.8, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out and that such inspection has not revealed any significant internal defects. Brief details of the testing procedure used are also to be included in this statement.

1.8.10 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.8.11 In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

1.8.12 When required by the conditions of approval for surface hardened forgings (*see* 1.5.6) additional test samples are to be processed at the same time as the forgings which they represent. These test samples are subsequently to be sectioned in order to determine the hardness, shape and depth of the locally hardened zone and which are to comply with the requirements of the approved specification.

1.9 Rectification of defects

1.9.1 Small surface imperfections may be removed by grinding or by chipping and grinding. Complete elimination of these imperfections is to be proved by magnetic particle or dye penetrant examination. At the discretion of the Surveyor, the resulting shallow grooves or depressions can be accepted, provided that they are blended by grinding.

1.9.2 Repairs by welding are not generally permitted, but special consideration will be given to such repairs where they are of a minor nature and in areas of low working stresses. In such cases, full details of the proposed repair and subsequent inspection procedures are to be submitted for the approval of the Surveyors prior to the commencement of the proposed rectification. A statement and/or sketch detailing the extent and location of all repairs, together with details of the post-weld heat treatment and non-destructive examination are to be provided for record purposes and are to be attached to the certificate.

1.9.3 Where fabrication welding is involved, *see* 1.2.14, any repair of defects is to be carried out in accordance with the approved welding procedure.

1.9.4 The forging manufacturer is to maintain records of repairs and subsequent inspections traceable to each forging. The records are to be presented to the Surveyor on request.

1.10 Identification

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished forgings to be traced to the original cast, forging process and heat treatment batch, and the Surveyor is to be given full facilities for so tracing the castings when required.

1.10.2 Forgings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all forgings which have been accepted:

(a) Identification number, cast number or other marking which will enable the full history of the forging to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of Surveyor responsible for inspection.
(d) Test pressure, where applicable.
(e) Date of final inspection.

1.10.3 Modified arrangements for the identification of small forgings manufactured in large numbers, as with closed-die forgings may be agreed with the Surveyor.

1.11 Certification

1.11.1 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each forging or batch of forgings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of forgings and steel quality.
(c) Identification number.
(d) Steelmaking process, cast number and chemical analysis of ladle samples.
(e) General details of heat treatment.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.2 The chemical composition of ladle samples is to include the content of all the elements detailed in the specific requirements.

1.11.3 Where applicable, the manufacturer is also to provide a signed statement regarding ultrasonic examination as required by 1.8.7, a report of magnetic particle inspection and a statement and/or sketch detailing all repairs by welding as required by 1.9.2.

1.11.4 When steel is not produced at the works at which it is forged, a certificate is to be supplied by the steelmaker stating the process of manufacture, cast number and the chemical composition of ladle samples. The works at which the steel was produced is to have been approved by LR, *see* 1.4.3.

■ *Section 2*
Forgings for ship and other structural applications

2.1 Scope

2.1.1 This Section gives the specific requirements for carbon-manganese steel forgings intended for ship and other structural applications such as rudder stocks, pintles, etc.

2.1.2 Where it is proposed to use an alloy steel, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval, *see* 1.4.3.

2.2 Chemical composition

2.2.1 For forgings to which structural items are to be attached by welding or which are intended for parts of a fabricated component, or are to be weld cladded or may be subject to weld repair in service, the chemical composition of ladle samples is to comply with the following:

Carbon	0,23% max.
Silicon	0,45% max.
Manganese 0,30–1,50% but not less than 3 times the actual carbon content for components which are not given a post-weld heat treatment	
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max.

For samples from forgings, the carbon content is not to exceed 0,26 per cent.

2.2.2 It is recommended that forgings for rudder stocks, pintles and rudder coupling bolts comply with 2.2.1 in order to obtain satisfactory weldability for any future repairs by welding in service.

2.2.3 For forgings not intended for welding the carbon content may be 0,65% max, *see* 3.2.1.

2.3 Heat treatment

2.3.1 Carbon-manganese steel forgings are to be:
(a) fully annealed; or
(b) normalized; or
(c) normalized and tempered at a temperature of not less than 550°C.
(d) quenched and tempered.

2.3.2 Alloy steel forgings are to be quenched and then tempered at a temperature of not less than 550°C. Alternatively, they may be supplied in the normalized and tempered condition, in which case the specified mechanical properties are to be agreed by LR.

2.4 Mechanical tests

2.4.1 At least one tensile specimen is to be taken from each forging or batch of forgings.

2.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, tensile test specimens are to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

2.4.3 Unless otherwise agreed between the manufacturer and the Surveyor, the test specimens are to be cut in a longitudinal direction.

2.4.4 The results of all tensile tests are to comply with the requirements given in Table 5.2.1 appropriate to the specified minimum tensile strength. Forgings may be supplied to any specified minimum tensile strength within the general limits given in Table 5.2.1, and intermediate values may be obtained by interpolation. *See* 2.4.6 for rudder stocks, pintles, and rudder coupling keys and bolts.

2.4.5 For large forgings, where tensile tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

2.4.6 For rudder stocks, pintles, and rudder coupling keys and bolts, the minimum specified yield strength is not to be less than 200 N/mm^2, *see* Table 13.2.4 in Pt 3, Ch 13.

2.4.7 Impact tests are required for rudder stocks to be fitted to vessels which have an ice class notation. The tests are to be carried out at minus 10°C and the average energy value is to be not less than 27J.

Table 5.2.1 Mechanical properties for ship and other structural applications

Steel type	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5,65\sqrt{S_o}$ min.%		Reduction of area min. %	
			Long.	Tang.	Long.	Tang.
C and C-Mn	180	360-480	28	20	50	35
	200	400-520	26	19	50	35
	220	440-560	24	18	50	35
	235	470-590	23	17	45	35
	240	480-600	22	16	45	30
	260	520-640	21	15	45	30
	280	560-680	20	14	40	27
	300	600-750	18	13	40	27
	320	640-790	17	12	40	27
	340	680-830	16	12	35	24
	360	720-870	15	11	35	24
	380	760-910	14	10	35	24
Alloy	350	550-570	20	14	50	35
	400	600-750	18	13	50	35
	450	650-800	17	12	50	35

■ Section 3 Forgings for shafting and machinery

3.1 Scope

3.1.1 Detailed in this Section are the requirements for carbon-manganese steel forgings for shafting and other items of machinery which are not within the scope of Sections 4 to 8.

3.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For main propulsion shafting in alloy steels, the specified minimum tensile strength is not to exceed 800 N/mm² (800–950 N/mm² acceptance range) and for other forgings is not to exceed 1100 N/mm² (1100–1300 N/mm² acceptance range).

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples for carbon and carbon-manganese steels is to comply with the following overall limits:

Carbon	0,65% max.
Silicon	0,45% max.
Manganese	0,30–1,50%
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max.

3.2.2 For alloy steels, *see* 1.4.3.

3.2.3 For forgings to which structural items are to be attached by welding, or which are intended for parts of a fabricated component, are to be of weldable quality, *see* 2.2.1.

3.3 Heat treatment

3.3.1 Forgings are to be:
(a) fully annealed; or
(b) normalized; or
(c) normalized and tempered; or
(d) quenched and tempered.
The tempering temperature is to be not less than 550°C.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on each forging, or each batch of forgings. Impact tests are not required except on screwshafts for ice service, *see* 3.4.12.

3.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, a tensile test is to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

3.4.3 A batch testing procedure may be used for hot rolled bars not exceeding 250 mm diameter, which are intended for the manufacture (by machining operations only) of straight shafting, bolts, studs and other machinery components of similar shape. A batch is to consist of either:
(a) material from the same piece provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge; or
(b) bars of the same diameter and cast, heat treated in the same furnace charge and with a total mass not exceeding 2,5 tonnes.

3.4.4 The test specimens are to be taken in the longitudinal direction but, at the discretion of the manufacturer and if agreed by the Surveyor, alternative directions or positions as shown in Figs. 5.3.1 to 5.3.3 may be used.

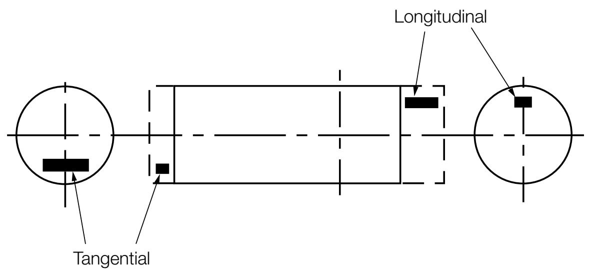


Fig. 5.3.1
Directions and positions of test specimens

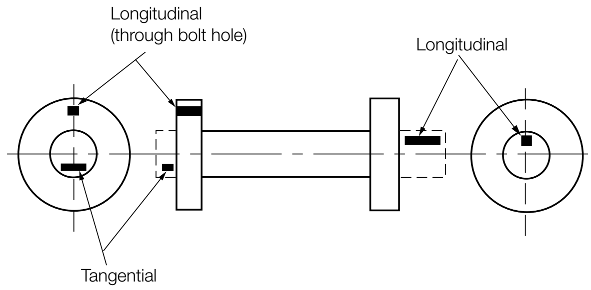


Fig. 5.3.2
Directions and positions of test specimens

3.4.5 For carbon-manganese steels, Table 5.3.1 gives the minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate values for other specified minimum tensile strengths should be calculated by interpolation.

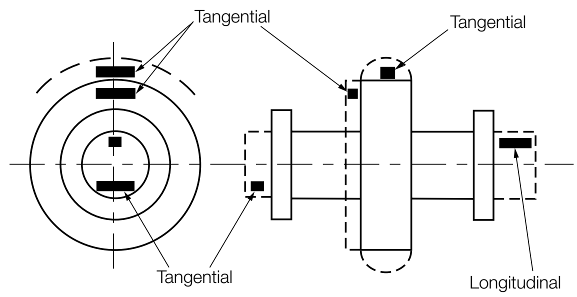


Fig. 5.3.3
Directions and positions of test specimens

3.4.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.1, except that for main propulsion shafting forgings the specified minimum tensile strength is to be not less than 400 N/mm^2 (400–520 N/mm^2 acceptance range) and not greater than 600 N/mm^2 (600–750 N/mm^2 acceptance range) *see* shaded area of Table 5.3.1.

3.4.7 The results of all tensile tests are to comply with the requirements given in Table 5.3.1 appropriate to the specified minimum tensile strength.

3.4.8 The minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels in alloy steel forgings are given in Table 5.3.2.

3.4.9 Forgings in alloy steels may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.2, and minimum yield stress, elongation and reduction of area, obtained by interpolation, except that for main propulsion shafting forgings the specified minimum tensile strength is not to exceed 800 N/mm^2 (800–950 N/mm^2 acceptance range) *see* shaded area of Table 5.3.2.

Table 5.3.1 **Mechanical properties for acceptance purposes: carbon and carbon-manganese steel forgings for machinery and shafting**

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5,65\sqrt{S_0}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
360-480	180	28	20	50	35
400-520	200	26	19	50	35
440-560	220	24	18	50	35
470-590	235	23	17	45	35
480-600	240	22	16	45	30
520-640	260	21	15	45	30
560-680	280	20	14	40	27
600-750	300	18	13	40	27
640-790	320	17	12	40	27
680-830	340	16	12	35	24
700-850 [2]	350	15	11	35	24
720-870 [2]	360	15	11	35	24
760-910 [2]	380	14	10	35	24

NOTES
1. For main propulsion shafting forgings, the specified minimum tensile strength is to be between 400 and 600 N/mm^2 (shaded area of Table) *see* 3.4.6.
2. Where the specified minimum tensile strength exceeds 700 N/mm^2, forgings are to be supplied only in the quenched and tempered condition.

Table 5.3.2 Mechanical properties for acceptance purposes: alloy steel forgings for machinery and shafting.

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5,65\sqrt{S_o}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
600-750	420	18	14	50	35
650-800	450	17	13	50	35
700-850	480	16	12	45	30
750-900	530	15	11	45	30
800 -950	580	14	10	40	27
850-1000	630	13	9	40	27
900-1100	690	13	9	40	27
950-1150	750	12	8	35	24
1000-1200	810	12	8	35	24
1050-1250	870	11	7	35	24
1100-1300	930	11	7	35	24

NOTE
For main propulsion shafting forgings, the minimum specified tensile strength is not to exceed 800 N/mm^2, *see* 3.4.9 (shaded area of Table).

3.4.10 The results of all tensile tests are to comply with the requirements given in Table 5.3.2 appropriate to the specified minimum tensile strength.

3.4.11 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 < 900	100
≥900	120

3.4.12 For screwshafts intended for ships with the notation Ice Class 1AS or 1A and where the connection between the propeller and the screwshaft is by means of a key, a set of three Charpy V-notch impact tests (longitudinal test) is to be made on material from the propeller end of each shaft. The tests are to be carried out at –10°C and the average energy value is to be not less than 27 J.

3.5 Non-destructive examination

3.5.1 Magnetic particle or dye penetrant testing is to be carried out on forgings for main propulsion shafting, on all connecting rod forgings and on the following components when they are intended for engines having a bore diameter larger than 400 mm:

- Cylinder covers
- Piston crowns
- Piston rods
- Tie rods
- Gear wheels for camshaft drives
- Bolts and studs for:
  - Cylinder covers
  - Crossheads
  - Main bearings
  - Connecting rod bearings.

3.5.2 The areas to be tested are those where experience shows defects are most likely to occur, and are to be mutually agreed between the Surveyor and the manufacturer. For tie rods, only threaded portions and the adjacent material over a length equal to that of the thread need be tested. The test results are to be to the Surveyor's satisfaction.

3.5.3 Ultrasonic testing is to be carried out on the following items:

(a) Shafts having a finished diameter of 250 mm or larger when intended for main propulsion or other essential services.
(b) All piston crowns and cylinder covers.
(c) Piston and connecting rods for engines having a bore diameter greater than 400 mm.

The test results are to be to the Surveyor's satisfaction.

■ *Section 4* Forgings for crankshafts

4.1 Scope

4.1.1 The specific requirements for solid forged crankshafts and forgings for use in the construction of fully built and semi-built crankshafts are detailed in this Section.

4.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition (*see* 1.4.3), heat treatment and mechanical properties are to be submitted for approval. The specified minimum tensile strength is not to exceed 1000 N/mm^2 (1000–1200 N/mm^2 acceptance range).

4.2 Manufacture

4.2.1 For closed die and continuous grain flow crankshafts forgings, where an allowance is given for design purposes, full details of the proposed method of manufacture are to be submitted for approval. In such cases, tests will be required to demonstrate that a satisfactory structure and grain flow are obtained. The number and positions of test specimens are to be agreed with LR.

4.2.2 For the manufacture of welded crankshafts, approval is required for the welding procedure.

4.2.3 For combined crankweb and pin forgings, the proposed method of forging is to be submitted for approval. It is recommended that these forgings be made by a folding method. Other methods which can be shown to produce sound forgings with satisfactory mechanical properties will be considered, but where the gapping method is used for cranks having a pin diameter exceeding 510 mm this will only be accepted provided that an upsetting operation is included in the manufacturing sequence. In general, the amount of work during the upsetting operation is to be such that the reduction in the original length of the ingot (after discard) or bloom is not less than 50 per cent.

4.2.4 Where crankwebs are flame cut from forged or rolled slabs, the procedure used is to be in accordance with 1.2.13, and additionally, unless specially agreed, a depth of at least 7,5 mm is to be removed by machining from all flame-cut surfaces.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

4.3.2 For alloy steel forgings which are to be nitrided, the phosphorus or sulphur contents are not to exceed 0,02 per cent.

4.4 Heat treatment

4.4.1 For forgings in all types of steels, heat treatment is to be either:
(a) normalizing and tempering, or
(b) quenching and tempering.
The temperature used for tempering is to be not less than 550°C.

4.4.2 Where it is proposed to surface harden crankshaft forgings by nitriding or induction hardening, full details of the proposed procedure are to be submitted as required by 1.5.6.

4.5 Mechanical tests

4.5.1 At least one tensile test specimen is to be taken from each forging.

4.5.2 For solid forged crankshafts, tests are to be taken in the longitudinal direction from the coupling end of each forging (test position A in Fig. 5.4.1). Where the mass, as heat treated but excluding test material, exceeds 3 tonnes, tests are to be taken from the end opposite the coupling, in addition (test position B in Fig. 5.4.1). Where the crankthrows are formed by machining or flame cutting, the second set of tests is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the coupling (test position C in Fig. 5.4.1).

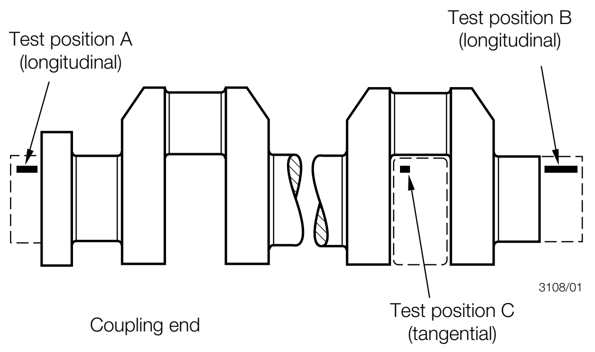


Fig. 5.4.1 Solid forged crankshaft

4.5.3 The number and position of test specimens from combined crankweb and pin forgings are to be in accordance with the requirements of the approved method of manufacture.

4.5.4 For other crankshaft forgings, tests are to be taken as detailed in Section 3, except that for crankwebs the test specimens are to be cut in a tangential direction.

4.5.5 As an alternative to 4.5.2, small solid forged crankshafts may be batch tested in accordance with 1.6.4, provided that, in addition, hardness tests are carried out on each forging.

4.5.6 Tables 5.4.1 to 5.4.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
400–520	200	26	19	110–150
440–560	220	24	18	125–160
480–600	240	22	16	135–175
520–640	260	21	15	150–185
560–680	280	20	14	160–200
600–750	300	18	13	175–215
640–790	320	17	12	185–230
680–830	340	16	12	200–240
720–870	350	15	11	210–250
760–910	380	14	18	225–265
Intermediate values may be obtained by interpolation				

Table 5.4.2 Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Normalized and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	330	18	14	175–215
650–800	355	17	13	190–235
700–850	380	16	12	205–245
750–900	405	15	11	215–260
800–950	430	14	10	235–275
Intermediate values may be obtained by interpolation				

Table 5.4.3 Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Quenched and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	420	18	14	175–215
650–800	450	17	13	190–235
700–850	380	16	12	205–245
750–900	530	15	11	215–260
800–950	590	14	10	235–275
850–1000	640	13	9	245–290
900–1100	690	13	9	260–320
950–1150	750	12	8	275–340
1000–1200	810	12	8	290–365
Intermediate values may be obtained by interpolation				

4.5.7 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.4.1 to 5.4.3.

4.5.8 The results of all tensile tests are to comply with the requirements of Table 5.4.1, 5.4.2 or 5.4.3 appropriate to the specified minimum tensile strength.

4.5.9 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 <900	100
≥900	120

4.5.10 For small crankshaft forgings which have been batch tested, the hardness values are to be not less than those given in Tables 5.4.1 to 5.4.3, as appropriate. The variation in hardness in each batch is to comply with the following:

Specified minimum tensile strength (N/mm^2)	Difference in hardness (Brinell number)
<600	not more than 25
≥600 <900	not more than 35
≥900	not more than 42

4.6 Non-destructive examination

4.6.1 Magnetic particle or dye penetrant testing as detailed in 1.8.5 is to be carried out on all forgings for crankshafts. Where applicable, this is to include all surfaces which have been flame-cut, but not subsequently machined during manufacture. Particular attention is to be given to the testing of the pins, journals and associated fillet radii of solid forged crankshafts and to the pins and fillet radii of combined web and pin forgings.

4.6.2 The manufacturer is to carry out an ultrasonic examination of all forgings as detailed in 1.8.7, except that for closed-die forgings this examination may, subject to approval, be confined to the initial production and to subsequent occasional checks.

■ *Section 5* Forgings for gearing

5.1 Scope

5.1.1 Provision is made in this Section for carbon-manganese and alloy steel forgings intended for use in the construction of gearing for main propulsion and for driving electric generators.

5.1.2 Gear wheel and rim forgings with a specified minimum tensile strength not exceeding 760 N/mm^2 (760–910 N/mm^2 acceptance range) may be made in carbon-manganese steel. Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 760 N/mm^2, and all pinion or pinion sleeve forgings, are to be made in a suitable alloy steel. Specifications for alloy steel components and for quill shafts, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval.

5.1.3 Forgings for flexible couplings, quill shafts and gear wheel shafts are to comply with the requirements of Section 3.

5.1.4 Manufacturers' test certificates for forgings may be accepted where the transmitted power does not exceed 220 kW (300 shp) for main propulsion and 100 kW (150 shp) for auxiliary drives.

5.2 Manufacture

5.2.1 All forgings are to be made with sufficient material to allow an adequate machining allowance on all surfaces for the removal of unsound or decarburized material.

5.2.2 The hardenability of the forged material is to be checked at random intervals using an end quench test complying with a National or International Standard.

5.2.3 The grain size is to be checked on a random basis in accordance with the testing and reporting procedures of ASTM E 112, or an equivalent National Standard, and is to be within the range 5 to 8.

5.2.4 The microstructure of the hardened case is to be mainly martensite, with a maximum content of 15 per cent of retained austenite.

5.3 Chemical composition

5.3.1 The chemical composition of ladle samples is to comply with 3.2.1. for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

5.4 Heat treatment

5.4.1 Except as provided in 5.4.4 and 5.4.5, forgings may be either normalized and tempered or quenched and tempered in accordance with the approved specification. The tempering temperature is to be not less than 550°C.

5.4.2 Where forgings are machined prior to heat treatment, the allowance left for final machining is to be sufficient to remove the decarburized surface material, taking into account any bending or distortion which may occur.

5.4.3 When the teeth of a pinion or gear wheel are to be surface hardened, i.e, carburized, nitrided or induction hardened, the proposed specification together with details of the process and practice are to be submitted for approval. For purposes of initial approval, the gear manufacturer is required to demonstrate by test that the surface hardening of the teeth is uniform and of the required depth and that it does not impair the soundness and quality of the steel.

5.4.4 Where induction hardening of nitriding is to be carried out after machining of the gear teeth, the forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

5.4.5 Forgings for gears which are to be carburized after final machining are to be supplied in either the fully annealed or the normalized and tempered condition, suitable for subsequent machining and carburizing.

5.5 Mechanical tests for through hardened, induction hardened or nitrided forgings

5.5.1 At least one tensile test specimen is to be taken from each forging in carbon or carbon-manganese steel, and at least one tensile test specimen from forgings in alloy steel. Sufficient test material is to be provided for this purpose and the test specimens are to be taken as follows:

(a) For pinion forgings where the finished diameter of the toothed portion exceeds 200 mm, tests are to be taken in a tangential direction and adjacent to the toothed portion (test position B in Fig. 5.5.1). Where the dimensions preclude the preparation of tests from this position, tests in a tangential direction are to be taken from the end of the journal (test position C in Fig. 5.5.1). If, however, the journal diameter is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1). Where the finished length of the toothed portion exceeds 1250 mm, tests are to be taken from each end.

(b) For small pinion forgings where the finished diameter of the toothed portion is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1).

(c) For gear wheel forgings, tests are to be taken in a tangential direction (from one of the test positions B in Fig. 5.5.2).

(d) For gear wheel rim forgings, tests are to be taken in a tangential direction (from one of the test positions A in Fig. 5.5.3). Where the finished diameter exceeds 2500 mm or the mass (as heat treated but excluding test material) exceeds 3 tonnes, tests are to be taken from two diametrically opposite positions (test positions A in Fig. 5.5.3).

(e) For pinion sleeve forgings, tests are to be taken in a tangential direction (from one of the test positions C in Fig. 5.5.4). Where the finished length exceeds 1250 mm, tests are to be taken from each end.

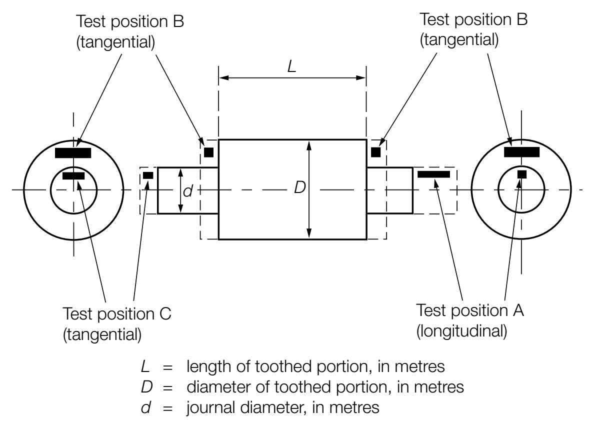


Fig. 5.5.1 Test positions for forgings for gearing

5.5.2 As an alternative to 5.5.1, small forgings may be batch tested in accordance with 1.6.4 provided that, in addition, hardness tests are carried out on each forging.

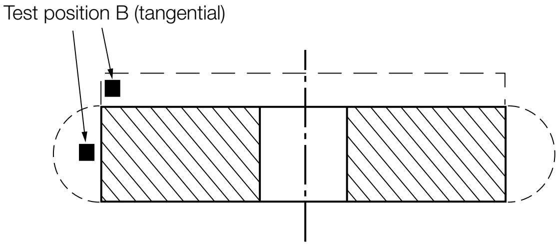


Fig. 5.5.2 Test position B

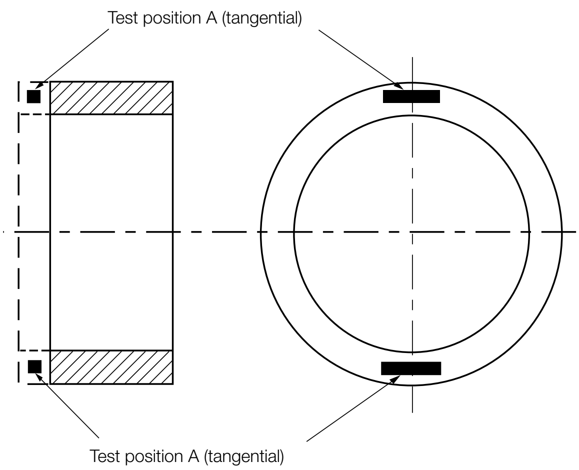


Fig. 5.5.3 Test position A

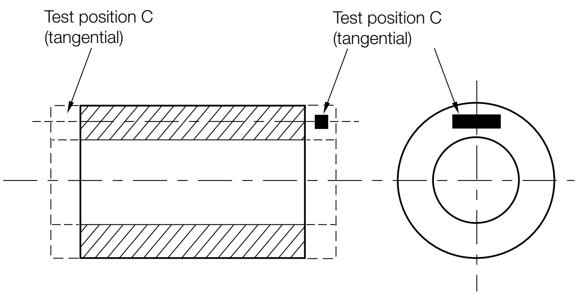


Fig. 5.5.4 Test position C

5.5.3 Tables 5.5.1 to 5.5.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

5.5.4 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.5.1 to 5.5.3.

Table 5.5.1 Mechanical properties for acceptance purposes: carbon-manganese steels for gear wheel and rim forgings

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
400–520	200	26	22	110–150
440–560	220	24	21	125–160
480–600	240	22	19	135–175
520–640	260	21	18	150–185
560–680	280	20	17	160–200
600–750	300	18	15	175–215
640–790	320	17	14	185–230
680–830	340	16	14	200–240
720–870	360	15	13	210–250
760– 910	380	14	12	225–265
Intermediate values may be obtained by interpolation				
NOTE When the specified minimum tensile strength exceeds 700 N/mm^2 forgings are to be supplied only in the quenched and tempered condition.				

Table 5.5.2 Mechanical properties for acceptance purposes: alloy steel gear wheel and rim forgings – Normalized and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
600–750	330	18	16	175–215
650–800	355	17	15	190–235
700–850	380	16	14	205–245
750–900	405	15	13	215–260
800–950	430	14	12	235–275
850–1000	455	13	11	245–290
Intermediate values may be obtained by interpolation				

5.5.5 The results of all tensile tests are to comply with the requirements of Table 5.5.1, 5.5.2 or 5.5.3, appropriate to the specified minimum tensile strength. Unless otherwise agreed, the specified minimum tensile strength is to be not less than 800 N/mm^2 (800–950 N/mm^2 acceptance range) for induction hardened or nitrided gear forgings.

5.5.6 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 <900	100
≥900	120

Table 5.5.3 Mechanical properties for acceptance purposes: alloy steel gear forgings – Quenched and tempered

Tensile strength N/mm^2 (*see* Notes 1 and 2)	Yield stress N/mm^2 minimum (*see* Note 2)	Elongation on 5,65 $\sqrt{S_o}$ % minimum A	B	C	Hardness Brinell
600–750	420	18	16	14	175–215
650–800	450	17	15	13	190–235
700–850	480	16	14	12	205–245
750–900	530	15	13	11	215–260
800–950	590	14	12	10	235–275
850–1000	640	13	11	9	245–290
900–1050	690	13	11	9	260–310
950–1100	750	12	10	8	275–330
1000–1150	810	12	10	8	290–340
1050–1200	870	11	9	7	310–365

Column A is applicable to tests from gear rims and to longitudinal tests from pinions
Column B is applicable to tests from gear wheels and to tangential tests from pinions
Column C is applicable to tests from pinion sleeves

Intermediate values may be obtained by interpolation

NOTES
1. For gear wheel and rim forgings the specified minimum tensile strength is not to exceed 850 N/mm^2.
2. For carburized gear forgings the requirements for minimum yield stress and maximum tensile strength are not applicable.

5.5.7 Hardness tests are to be carried out on all forgings after completion of heat treatment and prior to machining the gear teeth. The hardness is to be determined at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2500 mm, the number of test positions is to be increased to eight. Where the width of a gear wheel rim forging exceeds 1250 mm, the hardness is to be determined at eight positions at each end of the forging.

5.5.8 For small gear forgings which are batch tested, at least one hardness test is to be carried out on each forging.

5.5.9 The results of all hardness tests are to comply with the appropriate requirements of Tables 5.5.1 to 5.5.3. The difference between the highest and lowest values on any one forging is not to exceed the following:

Specified minimum tensile strength (N/mm^2)	Difference in hardness (Brinell number)
<600	25
≥600 <900	35
≥900	42

5.5.10 On nitrided or induction hardened components, hardness tests are also to be made on the teeth when surface hardening and grinding have been completed. The results are to comply with the approved specification.

5.6 Mechanical tests for carburized forgings

5.6.1 Sufficient test material is to be provided for preliminary tests at the forge and for final tests after completion of carburizing. For this purpose, duplicate sets of test material are to be taken from positions as detailed in 5.5.1, except that, irrespective of the dimensions or mass of the forging, tests are required from one position only, and in the case of forgings with integral journals are to be cut in a longitudinal direction. The test material which is to be used for measurements of case depth, hardness, grain size and residual austenite as well as mechanical properties is to be machined to a coupon of diameter of $\frac{D}{4}$ or 30 mm, whichever is less, where D is the finished diameter of the toothed portion.

5.6.2 For small forgings, where a system of batch testing is adopted, the test material may be prepared from surplus steel from the same cast provided that the forging reduction approximates to that of the actual gear forgings. The test samples are to be correctly identified and heat treated with the forgings they represent.

5.6.3 For preliminary tests at the forge, one set of test material is to be given a blank carburizing and heat treatment cycle simulating that which will be subsequently applied to the forgings.

5.6.4 For final acceptance tests, the second set of test material is to be blank carburized and heat treated together with the forgings which it represents.

5.6.5 At the discretion of the forgemaster or gear manufacturer, test samples of larger cross-section than in 5.6.1 may be either carburized or blank carburized, but these are to be machined to the required diameter prior to the final quenching and stress relieving heat treatment.

5.6.6 At least one tensile specimen is to be prepared from each sample of test material.

5.6.7 Unless otherwise agreed, the specified minimum tensile strength is to be not less than 750 N/mm^2, and the results of all tensile tests are to comply with the requirements given in Table 5.5.3.

5.6.8 Where it is proposed to adopt alternatives to the requirements of 5.6.1 to 5.6.7, full details are to be submitted to the Surveyor for consideration.

5.7 Non-destructive examination

5.7.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

5.7.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

5.7.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburized gearing the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, (i.e. depth to core hardness), is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 HV.

■ *Section 6*
Forgings for turbines

6.1 Scope

6.1.1 Provision is made in this Section for ferritic steel forgings for turbine rotors, discs and spindles, turbine-driven generator rotors and compressor rotors.

6.1.2 Plans for rotor forgings are to state whether the rotor is intended for propulsion or auxiliary machinery and the shaft power of auxiliary turbines. In the case of a rotor which is to be tested for thermal stability, the maximum operating temperature and the proposed test temperature are also to be stated.

6.1.3 Specifications of alloy steel forgings giving the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval with the plans of the components.

6.1.4 Where it is proposed to use rotors of welded construction, the compositions of the steels for the forgings are to be submitted for special consideration, together with details of the proposed welding procedure. Welding procedure tests may be required.

6.2 Manufacture

6.2.1 Forgings are to be manufactured in accordance with the requirements of Section 1, except that for rotors the forging reduction is to be not less than 2,5 to 1. Where an upsetting operation is included in the manufacturing procedure, the above requirement applies to the cross-sectional area of the upset bloom and not to that of the ingot.

6.3 Chemical composition

6.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

6.4 Heat treatment

6.4.1 Forgings are to be supplied in the heat treated condition, and the thermal treatment at all stages is to be such as to avoid the formation of hair-line cracks. At a suitable stage of manufacture, the forgings are to be reheated above the upper critical point to refine the grain, cooled in an approved manner and then tempered to produce the desired mechanical properties.

6.4.2 Where forgings receive their main heat treatment before machining, they are to be stress relieved after rough machining. Forgings which are heat treated in the rough machined condition need not be stress relieved provided that they have been slowly cooled from the tempering temperature.

6.4.3 The tempering and stress relieving temperatures are to be not less than 550°C for carbon and carbon-manganese steels, and not less than 600°C for alloy steels. The holding times and subsequent cooling rates are to be such that the forging in its final condition is free from harmful residual stresses.

6.4.4 Details of the proposed heat treatment for rotors of welded construction are to be submitted for approval.

6.5 Mechanical tests

6.5.1 At least one tensile test specimen, cut in a longitudinal direction, is to be taken from each rotor forging. For forgings exceeding both 3 tonnes in mass and 2000 mm in length, tests are to be taken from each end.

6.5.2 For rotor forgings of all main propulsion machinery and of auxiliary turbines exceeding 1100 kW, tangential and, where the dimensions permit, radial tensile tests are to be taken from the end of the body corresponding to the top end of the ingot, *see* Fig. 5.6.1.

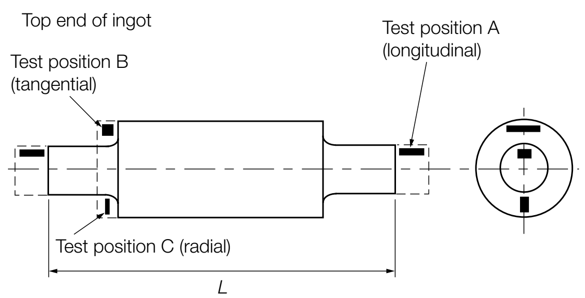


Fig. 5.6.1 Test positions for turbine rotor forgings

6.5.3 For each turbine disc, at least one tensile test specimen is to be cut in a tangential direction from material at the hub, *see* Fig. 5.6.2.

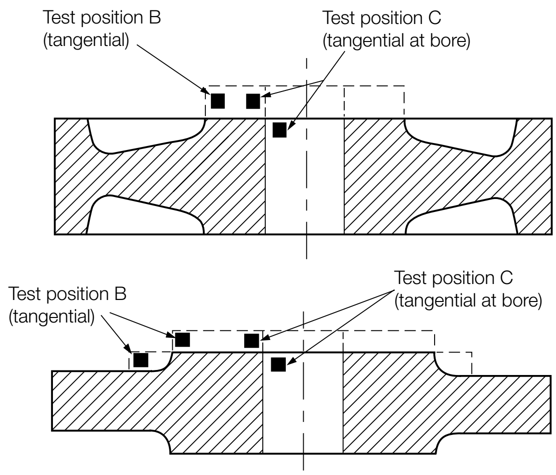


Fig. 5.6.2 Test positions for turbine disc forgings

6.5.4 For the tests required by 6.5.1 to 6.5.3, sufficient test material is to be left on each forging and is not to be removed until all heat treatment, including stress relieving, has been completed. In this connection, a thermal stability test does not form part of the heat treatment of a turbine forging. Any excess test material is not to be completely severed from a forging until all the mechanical tests have been completed with satisfactory results.

6.5.5 Tables 5.6.1 and 5.6.2 give the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 for alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.6.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for turbines – Normalized and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation $5,65\sqrt{S_o}$ % minimum			Reduction of area % minimum		
		A	B	C	A	B	C
400–520	200	26	22	18	50	40	35
440–560	220	24	21	17	50	40	35
480–600	240	22	19	15	45	35	30
520–640	260	21	18	14	45	35	30
560–680	280	20	17	13	40	30	25
600–720	300	18	15	12	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings
Columns B are applicable to tangential tests from rotor forgings
Columns C are applicable to radial tests from rotor forgings
Intermediate values may be obtained by interpolation

6.5.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.6.1 or Table 5.6.2.

Table 5.6.2 Mechanical properties for acceptance purposes: alloy steel forgings for turbines – Quenched and tempered or normalized and tempered

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum Normalized and tempered	Yield stress N/mm^2 minimum Quenched and tempered	Elongation on $5,65\sqrt{S_o}$ % minimum			Reduction of area %minimum		
			A	B	C	A	B	C
500 – 650	275	—	22	20	18	50	40	35
550 – 700	300	—	20	18	16	50	40	35
600 – 750	330	410	18	16	14	50	40	35
650 – 800	355	450	17	15	13	50	40	35
700 – 850	385	490	16	14	12	45	35	30
750 – 900	—	530	15	13	11	45	35	30
800 – 950	—	590	14	12	10	45	35	30
850 – 1000	—	640	13	11	9	40	30	25
900 – 1050	—	690	13	11	9	40	30	25
950 – 1100	—	750	12	10	8	40	30	25
1000 – 1150	—	810	12	10	8	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings
Columns B are applicable to tangential tests from rotor and spindle forgings, and to tangential tests from discs – test position B in Fig. 5.6.2
Columns C are applicable to radial test from rotor forgings and to tangential tests from discs – test position C in Fig. 5.6.2
Intermediate values may be obtained by interpolation

6.5.7 The results of all tensile tests are to comply with the requirements of Table 5.6.1 or Table 5.6.2 appropriate to the specified minimum tensile strength. For monobloc rotor forgings, the specified minimum tensile strength is not to exceed 800 N/mm^2.

6.6 Non-destructive examination

6.6.1 The end faces of the body of rotor forgings and the end faces of the boss and the bore surface of each turbine disc are to be machined to a fine smooth finish for visual and magnetic particle examination.

6.6.2 The manufacturer is to carry out an ultrasonic examination of each forging and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

6.6.3 Rotor forgings for propulsion machinery and for auxiliary turbines exceeding 1100 kW are to be hollow bored for internal examination. The surface of the bore is to have a fine smooth finish and is to be examined by means of an optical instrument of suitable magnification. Where the bore size permits, magnetic particle examination is also to be carried out. These examinations are to be confirmed by the Surveyor. Alternatively, an approved method of ultrasonic examination may be accepted instead of hollow boring. Details of the proposed method of ultrasonic examination are to be submitted for special consideration.

6.7 Thermal stability tests

6.7.1 Thermal stability tests after heat treatment and rough machining of the turbine rotors, referred to in the relevant Rules dealing with design and construction, are to be undertaken in properly constructed furnaces, using accurate and reliable measuring equipment. Each test is to be carried out in accordance with the following recommended procedure:

(a) Five bands are to be machined concentric with the axis of rotation. Two of these are to be reference bands and are to be positioned at or near the locations of the bearings. The remaining three bands are to be test bands located one as near as possible to the mid-length, and the other two near each end of the body. Where the length of a rotor is such that five bands cannot be provided, alternative proposals are to be submitted to the Surveyor for his approval.
(b) Four positions, 90° apart, are to be stamped A, B, C and D on the coupling end of the rotor.
(c) The whole of the body, and as much of the shaft at either end as will include the positions of the glands, is to be enclosed in the furnace. In the case of a rotor having an overhung astern wheel, the astern wheel is also to be enclosed in the furnace during the first test.
(d) The rotor is to be rotated at a uniform and very low speed.
(e) The deflections at all bands are to be recorded at the A, B, C and D positions. Initial cold readings are to be taken prior to heating.
(f) The rotor is to be heated uniformly and slowly. Temperatures are to be recorded continuously at the surface of the rotor and, if practicable, in the bore at the mid-length of the body. In no circumstances is the surface temperature to exceed the temperature at which the rotor was tempered. During heating, the rate of rise of temperature is to be such as to avoid excessive temperature gradients in the rotor.
(g) The maximum or holding temperature is to be not less than 28°C above the maximum operating temperature of the rotor. For the purposes of the test, the holding period is to start when the rotor has attained a uniform and specified temperature. The rotor is to be held under the specified temperature conditions until not less than three consecutive hourly readings of deflections show the radial eccentricity to be constant within 0,006 mm on all test bands.
(h) The turbine rotor is to be rotated during cooling until the temperature is not more than 100°C. The rate of cooling is to be such as to avoid excessive temperature gradients in the rotor.
(j) Final cold readings are to be taken.

6.7.2 The movements of the axis of the rotor in relation to the reference bands are to be determined from polar plots of the deflection readings. The radial movement of the shaft axis, as determined by the difference between the final hot and the final cold movements, is not to exceed 0,025 mm on any one band. As verification that test equipment and conditions are satisfactory, it is required that similar determinations of differences between initial cold and final cold movements do not exceed 0,025 mm on any one band.

6.7.3 If the results of the test on a rotor fail to meet either or both of the requirements in 6.7.2, the test may be repeated if requested by the maker and agreed by the Surveyor. In the case of a rotor failing to meet the requirements of a thermal stability test, the rotor is deemed unacceptable. Proposals for the rectification of thermal instability of a rough machined rotor are to be submitted for special consideration.

■ *Section 7*
Forgings for boilers, pressure vessels and piping systems

7.1 Scope

7.1.1 Provision is made in this Section for carbon-manganese and low alloy steel forgings intended for use in the construction of boilers, pressure vessels and piping systems where the design temperature is not lower than 0°C.

7.1.2 In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

7.1.3 Forgings used in the construction of equipment for the containment of liquefied gases are to comply with the requirements of Section 8, except for those used in piping systems, where the design temperature is not lower than 0°C. Forgings for other pressure vessels and piping systems, where the use of steels with guaranteed impact properties at low temperatures is required, are also to comply with Section 8.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the appropriate requirements of Table 5.7.1.

7.3 Heat treatment

7.3.1 Carbon-manganese steel forgings are to be normalized, normalized and tempered or quenched and tempered.

7.3.2 Alloy steel forgings are to be normalized and tempered or quenched and tempered.

7.3.3 No forging is to be fully heat treated more than twice.

7.4 Mechanical tests

7.4.1 Except as provided in 7.4.2 and 7.4.4, at least one tensile test is to be taken from each forging and, where the dimensions and shape allow, the test specimen is to be cut in the longitudinal direction.

7.4.2 On seamless drums and headers which are initially forged with open ends, test material is to be provided at each end of each forging. Where forged with one solid end, test material is to be provided at the open end only. Except where the ends are to be subsequently closed by forging, the test material is not to be removed until heat treatment has been completed. Where the ends are to be closed, rings of test material are to be cut off prior to the closing operation and are to be heat treated with the finished forging. In all cases, the test specimens are to be cut in the circumferential direction.

7.4.3 Unless otherwise agreed, tensile test specimens are to be taken with their axis at approximately 12,5 mm below the surface of the forging.

7.4.4 Small forgings may be batch tested in accordance with 1.6.4 provided that hardness tests are carried out on each forging. In such cases, the mass of each forging is not to exceed 1 tonne and that of the batch is not to exceed 10 tonnes and the hardness values are to accord with Table 5.7.2.

7.4.5 If required by the Surveyors or by the Fabricators, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order, together with agreed details of the simulated heat treatment and the mechanical properties which can be expected.

7.4.6 Except as provided in 7.4.7, the results of all tensile tests are to comply with the requirements given in Table 5.7.2 appropriate to the specified minimum tensile strength.

7.4.7 Where tests are taken at a depth greater than 12,5 mm from the surface or where they are taken in a transverse direction, the mechanical properties which can be expected are to be agreed.

7.4.8 On seamless drums and headers where tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

7.4.9 For small batch-tested forgings, the hardness values are to comply with the requirements of Table 5.7.2 appropriate to the specified minimum tensile strength. If forgings of more than one thickness are to be supplied from one cast, then the test is to be made on the thickest forging.

7.5 Non-destructive examination

7.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

Table 5.7.1 Chemical composition

Type of steel	Tensile strength N/mm^2	Chemical composition of ladle samples %							
		C max.	Si	Mn	P max.	S max.	Al	Residual elements	
Carbon-manganese	410–530	0,20	0,10–0,40	0,50–1,20	0,030	0,025	(*See* Notes 1 and 3)	Ni 0,40 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,80 max.	
	460–580	0,23		0,80–1,40					
	490–610	0,25		0,90–1,70					
								Cr	Mo
Alloy steel 1Cr$^1/_2$Mo	440–590	0,18	0,15–0,40	0,40–0,70	0,030	0,025	0,020 max. (*See* Note 2)	0,85–1,15	0,45–0,65
2$^1/_4$ Cr1Mo	490–640	0,15						2,0–2,5	0,90–1,20

NOTES
1. Fine grained steels are to contain:
   aluminium (acid soluble) 0,015% min. or
   aluminium (total) 0,018% min.
2. For alloy steels, aluminium (acid soluble) 0,020% max.
   The determination of the aluminium (total) content is acceptable provided the above value is not exceeded.
3. Niobium may be used as a grain refiner in place of aluminium, in which case the content is to be in the range 0,01% to 0,06%.

Table 5.7.2 Mechanical properties for acceptance purposes

Type of steel	Diameter or equivalent thickness mm	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Hardness Brinell
Carbon-manganese not specifically fine grained	≤100	215	410–530	20	110–155
	>100 ≤500	205			
	≤100	245	460–580	18	130–170
	>100	235			
	≤100	265	490–610	16	140–180
	>100	255			
Carbon-manganese, fine grained	≤100	235	410–530	20	110–155
	>100 ≤250	220			
	≤100	275	460–580	18	130–170
	>100 ≤250	255			
	≤100	305	490–610	16	140–180
	>100 ≤250	280			
Alloy steel 1Cr$^1/_2$Mo	–	275	440–590	19	110–160
2$^1/_4$Cr1Mo	–	275	490–640	18	140–185

Table 5.7.3 Mechanical properties for design purposes

Type of steel	Diameter or equivalent thickness mm	Tensile strength N/mm^2	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
			Temperature °C											
			50	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese not specifically fine grained	≤100	410–530	196	192	188	181	168	150	142	138	136	—	–	—
	>100		183	178	175	170	162	150	142	138	136	—	—	—
	≤100	460–580	227	222	218	210	194	176	168	162	158	—	—	—
	>100		212	206	203	197	188	176	168	162	158	—	—	—
	≤100	490–610	245	240	236	227	210	192	183	177	172	—	—	—
	>100		229	222	219	212	203	192	183	177	172	—	—	—
Carbon-manganese fine grained	≤100	410–530	222	215	204	188	171	152	141	134	130	—	—	—
	>100		207	200	190	175	164	152	141	134	130	—	—	—
	≤100	460–580	262	251	236	217	198	177	167	158	153	—	—	—
	>100		244	233	220	202	190	177	167	158	153	—	—	—
	≤100	490–610	286	272	256	234	213	192	182	173	168	—	—	—
	>100		266	253	238	218	205	192	182	173	168	—	—	—
Alloy steel 1Cr$^1/_2$Mo	—	410–560	254	241	224	213	197	184	170	162	157	151	146	145
2$^1/_4$ Cr1Mo	—	490–640	268	261	253	245	236	230	224	218	205	189	167	145

7.6 Pressure tests

7.6.1 Where applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

7.7 Mechanical properties for design purposes

7.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 5.7.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 5.7.3.

7.7.2 Where verification is required, at least one tensile test at the proposed design or other agreed temperature is to be made on each forging or each batch of forgings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

7.7.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 5.7.4 and may be used for design purposes.

Table 5.7.4 Mechanical properties for design purposes: estimated average values for stress to rupture in 100 000 hours (units N/mm²)

Temperature °C	Grades of steel		
	Carbon-manganese	1 Cr 1/2 Mo	2 1/4 Cr 1Mo
380	227	—	—
390	203	—	—
400	179	—	—
410	157	—	—
420	136	—	—
430	117	—	—
440	100	—	—
450	85	290	—
460	73	262	—
470	63	235	210
480	55	208	186
490	—	181	165
500	—	155	145
510	—	129	128
520	—	103	112
530	—	80	98
540	—	62	84
550	—	49	72
560	—	42	61
570	—	36	49
580	—	32	—
590	—	29	—

■ *Section 8* Ferritic steel forgings for low temperature service

8.1 Scope

8.1.1 The requirements for carbon-manganese and nickel steels suitable for low temperature service are detailed in this Section. They are applicable to all forgings used for the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases and, where the design temperature is less than 0°C, to forgings for the piping systems.

8.1.2 The requirements are also applicable to forgings for other pressure vessels and pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

8.1.3 In all cases, details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

8.1.4 In addition to the steels in this Section, the austenitic stainless steels detailed in Section 9 may also be used for low temperature applications.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is, in general, to comply with the requirements given in Table 5.8.1.

8.3 Heat treatment

8.3.1 Forgings are to be normalized, normalized and tempered or quenched and tempered in accordance with the approved specification.

8.4 Mechanical tests

8.4.1 At least one tensile and three Charpy V-notch impact test specimens are to be taken from each forging or each batch of forgings. Where the dimensions and shape allow, the test specimens are to be cut in a longitudinal direction.

8.4.2 The impact tests are to be carried out at a temperature appropriate to the type of steel and for the proposed application. Where forgings are intended for ships for liquefied gases, the test temperature is to be in accordance with the requirements given in Table 3.6.3 in Chapter 3.

8.4.3 The results of all tensile tests are to comply with the approved specification.

8.4.4 The average energy values for impact tests are also to comply with the approved specification and generally with the requirements of Ch 3,6. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4 for re-test procedures.

Table 5.8.1 Chemical composition of ferritic steel forgings

<table>
<tr><th rowspan="2">Grade of steel</th><th rowspan="2">C
%</th><th rowspan="2">Si
%</th><th rowspan="2">Mn
%</th><th rowspan="2">Ni
%</th><th rowspan="2">P
%</th><th rowspan="2">S
%</th><th rowspan="2">Residual
elements %</th><th colspan="2">Grain refiners %</th></tr>
<tr><th>Al</th><th>Other</th></tr>
<tr><td>LT–AH (AH40)
LT–DH (DH40)
LT–EH (EH40)</td><td>0,18
max.</td><td rowspan="2">0,50
max.</td><td rowspan="2">0,90–1,60</td><td>0,40
max.</td><td>0,035
max.</td><td>0,030
max.</td><td rowspan="2">Cu 0,35 max.
Cr 0,20 max.
Mo 0,08 max.

Total 0,60 max.</td><td rowspan="6">Total
0,020 min

Acid soluble
0,015 min</td><td rowspan="2">(*See* Note)

Nb 0,02 – 0,05
V 0,03 – 0,10
Ti 0,02 max.</td></tr>
<tr><td>LT–FH (FH40)</td><td>0,16
max.</td><td>0,80
max.</td><td rowspan="5">0,025
max</td><td>0,025
max.</td></tr>
<tr><td>1½Ni</td><td>0,18
max.</td><td rowspan="4">0,10 – 0,35</td><td>0,30–1,50</td><td>1,30–1,70</td><td rowspan="4">0,020
max.</td><td rowspan="4">Cu 0,35 max.
Cr 0,25 max.
Mo 0,08 max.

Total 0,60 max.</td><td rowspan="4"></td></tr>
<tr><td>3½Ni</td><td>0,15
max.</td><td rowspan="3">0,30–0,90</td><td>3,20–3,80</td></tr>
<tr><td>5Ni</td><td>0,12
max.</td><td>4,70–5,30</td></tr>
<tr><td>9 Ni</td><td>0,10
max.</td><td>8,50–10,0</td></tr>
<tr><td colspan="10">NOTE
The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.</td></tr>
</table>

8.5 Non-destructive examination

8.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

8.6 Pressure tests

8.6.1 When applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

■ *Section 9*
Austenitic stainless steel forgings

9.1 General

9.1.1 Forgings in austenitic stainless steels are acceptable for use in the construction of cargo tanks, storage tanks and piping systems for chemicals and liquefied gases. They may also be accepted for elevated temperature service in boilers.

9.1.2 Where it is proposed to use forgings in these types of steels, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval. These are to comply, in general, with the requirements of Ch 3,7 for austenitic steel plates.

9.1.3 Unless otherwise agreed, impact tests are not required for acceptance purposes. Where they are required, tests are to be made on longitudinal specimens at minus 196°C and the minimum average energy requirement is to be 41J.

9.2 Mechanical properties for design purposes

9.2.1 Where austenitic stainless steel forgings are intended for service at elevated temperatures, the nominal values for the minimum one per cent proof stress at temperatures of 100°C and higher given in Table 5.9.1 may be used for design purposes. Verification of these values is not required except for material complying with a National or proprietary specification in which the elevated temperature properties proposed for design purposes are higher than those given in Table 5.9.1.

9.3 Non-destructive examination

9.3.1 Non-destructive examination is to be carried out in accordance with the requirements of the approved forging drawing and specification or as otherwise agreed between the manufacturer, purchaser and Surveyor.

9.4 Intergranular corrosion tests

9.4.1 Where corrosive conditions are anticipated in service, intergranular corrosion tests are required on forgings in Grades 304, 316 and 317. Such tests may not be required for Grades 304L, 316L, 321 and 347.

Table 5.9.1 Mechanical properties for design purposes: austenitic stainless steels

Grade	Nominal 1% proof stress (N/mm^2) at a temperature of												
	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C	650°C	700°C
304L	168	150	137	128	122	116	110	108	106	102	100	96	93
316L	177	161	149	139	133	127	123	119	115	112	110	107	105
316LN	238	208	192	180	172	166	161	157	152	149	144	142	138
321	192	180	172	164	158	152	148	144	140	138	135	130	124
347	204	192	182	172	166	162	159	157	155	153	151	—	—

9.4.2 When an intergranular corrosion test is specified, it is to be carried out in accordance with the procedure given in Ch 2,8.1.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for boiler tubes, superheater tubes and pipes intended for use in the construction of boilers, pressure vessels and pressure piping systems.

1.1.2 In addition to specifying mechanical properties for the purpose of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

1.1.3 Except for pipes for Class III pressure systems (as defined in the relevant Rules), all pipes and tubes are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2, 3, 4, 5 and 6.

1.1.4 Steels intended for the piping systems for liquefied gases where the design temperature is less than 0°C are to comply with the specific requirements of Section 4 or 5.

1.1.5 As an alternative to 1.1.3 and 1.1.4, pipes or tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.6 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

1.1.7 Pipes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of an acceptable National specification. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of material. Forge butt welded pipes are not acceptable for oil fuel systems, heating coils in oil tanks, primary refrigerant systems and other applications where the pressure exceeds 4,0 bar (4,1 kgf/cm^2).

1.2 Manufacture

1.2.1 Pipes for Class I and II pressure systems, boiler and superheater tubes are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR'). The steel used is to be manufactured and cast in ingot moulds or by an approved continuous casting process as detailed in Ch 3,1.3.

1.2.2 Unless a particular method is requested by the purchaser, pipes and tubes may be manufactured by any of the following methods:
- Hot finished seamless.
- Cold finished seamless.
- Electric resistance or induction welded.
- Cold finished electric resistance or induction welded.
- Electric fusion welded.

1.2.3 Care is to be taken during manufacture that the pipe or tube surfaces coming in contact with any non-ferrous metals or their compounds are not contaminated to such an extent as could prove harmful during subsequent fabrication and operation.

1.3 Quality

1.3.1 All pipes and tubes are to have a workmanlike finish and are to be clean and free from such surface and internal defects as can be established by the specified tests.

1.3.2 All pipes and tubes are to be reasonably straight. The ends are to be cut nominally square with the axis of the pipe or tube, and are to be free from excessive burrs.

1.4 Dimensional tolerances

1.4.1 The tolerances on the wall thickness and diameter of pipes and tubes are to be in accordance with an acceptable National specification.

1.5 Chemical composition

1.5.1 The requirements for the chemical composition of ladle samples and acceptable methods of deoxidation are detailed in subsequent Sections in this Chapter.

1.6 Heat treatment

1.6.1 All pipes and tubes are to be supplied in the condition detailed in the relevant specific requirements.

1.7 Test material

1.7.1 Pipes and tubes are to be presented for test in batches. The size of a batch and the number of tests to be performed are dependent on the application.

1.7.2 Where heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size, manufactured from the same types of steel and subjected to the same finishing treatment in a continuous furnace, or heat treated in the same furnace charge in a batch type furnace.

1.7.3 Where no heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size manufactured by the same method from material of the same type of steel.

1.7.4 For pipes for Class I pressure systems and boiler and superheater tubes, at least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests at ambient temperature.

1.7.5 For pipes for Class II pressure systems, each batch is to contain not more than the number of lengths given in Table 6.1.1. Tests are to be carried out on at least one pipe selected at random from each batch or part thereof.

Table 6.1.1 Batch sizes for pipes for Class II pressure systems

Outside diameter mm	Number in batch
≤323,9	200 pipes as made
>323,9	100 pipes as made

1.8 Dimensions of test specimens and test procedures

1.8.1 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

1.9 Visual and non-destructive testing

1.9.1 All pipes for Class I and II pressure systems, boiler and superheater tubes, are to be presented for visual examination and verification of dimensions. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the pipes and tubes to be carried out.

1.9.2 For welded pipes and tubes, the manufacturer is to employ suitable non-destructive methods for the quality control of the welds. It is preferred that this examination is carried out on a continuous basis.

1.10 Hydraulic test

1.10.1 Each pipe and tube is to be subjected to a hydraulic test at the manufacturer's works.

1.10.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 140 bar (143 kgf/cm^2):

$$P = \frac{20st}{D} \left(P = \frac{200st}{D}\right)$$

where
- P = test pressure, in bar (kgf/cm^2)
- D = nominal outside diameter, in mm
- t = nominal wall thickness, in mm
- s = 80 per cent of the specified minimum yield stress, in N/mm^2 (kgf/mm^2), for ferritic steels and 70 per cent of the specified minimum, 1,0 per cent proof stress, in N/mm^2 (kgf/mm^2), for austenitic steels. These relate to the values specified for acceptance testing at ambient temperature.

1.10.3 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted. Where it is proposed to adopt a test pressure other than that determined as in 1.10.2, the proposal will be subject to special consideration.

1.10.4 Subject to special approval, either an ultrasonic or eddy current test can be accepted in lieu of the hydraulic test.

1.11 Rectification of defects

1.11.1 Surface imperfections may be removed by grinding provided that the thickness of the pipe or tube after dressing is not less than the required minimum thickness. The dressed area is to be blended into the contour of the tube.

1.11.2 By agreement with the Surveyor, the repair of minor defects by welding can be accepted, subject to welding procedure tests which demonstrate acceptable properties appropriate for the grade of pipe to be repaired. Weld procedure tests are to be subjected to the same heat treatment as will be applied to the actual pipes after weld repair.

1.11.3 The repaired area is to be tested by magnetic particle examination, or, for austenitic steels, by liquid penetrant examination on completion of welding, heat treatment and surface grinding.

1.12 Identification

1.12.1 Pipes and tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:
(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the specification or grade of steel.
(d) Identification number and/or initials which will enable the full history of the item to be traced.
(e) The personal stamp of the Surveyor responsible for the final inspection.

1.12.2 It is recommended that hard stamping be restricted to the end face, but it may be accepted in other positions in accordance with National Standards and practices.

1.13 Certification

1.13.1 The manufacturer is to provide the Surveyor with copies of the test certificate or shipping statement for all material which has been accepted.

1.13.2 Each test certificate is to contain the following particulars:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Specification or the grade of material.
(e) Description and dimensions.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples.
(h) Mechanical test results, and results of the intercrystalline corrosion tests where applicable.
(j) Condition of supply.

1.13.3 The chemical composition stated on the certificate is to include the content of all the elements detailed in the specific requirements. Where rimming steel is supplied, this is to be stated on the certificate.

1.13.4 When steel is not produced at the pipe or tube mill, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the ladle analysis.

1.13.5 The steel manufacturer's works is to be approved by LR.

■ *Section 2*
Seamless pressure pipes

2.1 Scope

2.1.1 Provision is made in this Section for seamless pressure pipes in carbon, carbon-manganese and low alloy steels.

2.1.2 Where pipes are used for the manufacture of pressure vessel shells and headers, the requirements for forgings in Ch 5,7 are applicable where the wall thickness exceeds 40 mm.

2.2 Manufacture and chemical composition

2.2.1 Pipes are to be manufactured by a seamless process and may be hot or cold finished.

2.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.2.1.

Table 6.2.1 Chemical composition of seamless pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %											
			C	Si	Mn	S max.	P max.	Residual elements						
								Ni	Cr	Mo	Cu	Sn	V	Al
Carbon and carbon-manganese	320	Semi-killed or killed	≤0,16	–	0,40–0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.						
	360		≤0,17	≤0,35	0,40–0,80	0,045	0,045							
	410	Killed	≤0,21	≤0,35	0,40–1,20	0,045	0,045							
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045							
	490		≤0,23	≤0,35	0,80–1,50	0,045	0,045							
1Cr$^1/_2$Mo	440	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30 max.	0,70–1,10	0,45 – 0,65	0,25 max.	0,03 max.	—	≤0,020
2$^1/_4$Cr1Mo	410 490	Killed	0,08–0,15	0,10–0,50	0,40–0,70	0,040	0,040	0,30 max.	2,0–2,5	0,90–1,20	0,25 max.	0,03 max.	—	≤0,020
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	460	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30	0,30–0,60	0,50–0,70	0,25 max.	0,03 max.	0,22–0,32	≤0,020

2.3 Heat treatment

2.3.1 Pipes are to be supplied in the condition given in Table 6.2.3.

2.4 Mechanical tests

2.4.1 All pipes are to be presented in batches as defined in Section 1.

2.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

2.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.2.2.

2.5 Mechanical properties for design

2.5.1 Values for nominal minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 6.2.4 and are intended for design purposes only. Verification of these values is not required, except for materials complying with National or proprietary specification where the elevated temperature properties used for design are higher than those given in Table 6.2.4.

2.5.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each cast. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature and tested in accordance with the procedures given in Chapter 2. If tubes or pipes of more than one thickness are supplied from one cast, the test is to be made on the thickest tube or pipe.

Table 6.2.3 Heat treatment

Type of steel		Condition of supply
Carbon and carbon-manganese		
Hot finished		Hot finished (*see* Note 1) Normalized (*see* Note 2)
Cold finished		Normalized (*see* Note 2)
Alloy steel		
1Cr1/2Mo		Normalized and tempered
21/4Cr1Mo	Grade 410	Fully annealed
	Grade 490	Normalized and tempered 650—780°C
	Grade 490	Normalized and tempered 650—750°C
1/2Cr1/2Mo1/4V		Normalized and tempered

NOTES
1. Provided that the finishing temperature is sufficiently high to soften the material.
2. Normalized and tempered at the option of the manufacturer.

2.5.3 As an alternative to 2.5.2, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under the supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes, but at the discretion of the Surveyors occasional check tests of this type may be requested.

2.5.4 Values for the estimated average stress to rupture in 100 000 hours are given in Table 6.2.5 and may be used for design purposes.

Table 6.2.2 Mechanical properties for acceptance purposes: seamless pressure pipes (maximum wall thickness 40 mm), *see* 2.1.2

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)
Carbon and carbon-manganese	320	195	320—440	25	0,10	4*t*
	360	215	360—480	24	0,10	
	410	235	410—530	22	0,08	
	460	265	460—580	21	0,07	
	490	285	490—610	21	0,07	
1Cr1/2Mo	440	275	440—590	22	0,07	4*t*
21/4Cr1Mo	410 (*see* Note 1)	135	410—560	20	0,07	4*t*
	490 (*see* Note 2)	275	490—640	16		
1/2Cr1/2Mo1/4V	460	275	460—610	15	0,07	4*t*

NOTES
1. Annealed condition.
2. Normalized and tempered condition.

Table 6.2.4 Mechanical properties for design purposes: seamless pressure pipes

Type of steel	Grade	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
		Temperature °C											
		50	100	150	200	250	300	350	400	450	500	550	600
Carbon and carbon-manganese	320	172	168	158	147	125	100	91	88	87	—	—	—
	360	192	187	176	165	145	122	111	109	107	—	—	—
	410	217	210	199	188	170	149	137	134	132	—	—	—
	460	241	234	223	212	195	177	162	159	156	—	—	—
	490	256	249	237	226	210	193	177	174	171	—	—	—
1Cr$^1/_2$Mo	440	254	240	230	220	210	183	169	164	161	156	151	—
2$^1/_2$Cr1Mo	410 (*see* Note 1)	121	108	99	92	85	80	76	72	69	66	64	62
	490 (*see* Note 2)	268	261	253	245	236	230	224	218	205	189	167	145
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	460	266	259	248	235	218	192	184	177	168	155	148	—

NOTES
1. Annealed condition.
2. Normalized and tempered condition.

Table 6.2.5 Mechanical properties for design purposes: seamless pressure pipes – Estimated values for stress to rupture in 100 000 hours (units N/mm^2)

Temperature °C	Carbon and carbon-manganese		1Cr$^1/_2$Mo	2$^1/_4$Cr1Mo		$^1/_2$Cr$^1/_2$Mo$^1/_4$V
	Grade 320 360 410	Grade 460 490	Grade 440	Grade 410 Annealed	Grade 490 Normalized and tempered (*see* Note)	Grade 460
380	171	227	—	—	—	—
390	155	203	—	—	—	—
400	141	179	—	—	—	—
410	127	157	—	—	—	—
420	114	136	—	—	—	—
430	102	117	—	—	—	—
440	90	100	—	—	—	—
450	78	85	—	196	221	—
460	67	73	—	182	204	—
470	57	63	—	168	186	—
480	47	55	210	154	170	218
490	36	47	177	141	153	191
500	—	41	146	127	137	170
510	—	—	121	115	122	150
520	—	—	99	102	107	131
530	—	—	81	90	93	116
540	—	—	67	78	79	100
550	—	—	54	69	69	85
560	—	—	43	59	59	72
570	—	—	35	51	51	59
580	—	—	—	44	44	46

NOTE
When the tempering temperature exceeds 750°C, the values for Grade 410 are to be used.

■ *Section 3* Welded pressure pipes

3.1 Scope

3.1.1 Provision is made in this Section for welded pressure pipes in carbon, carbon-manganese and low alloy steels.

3.2 Manufacture and chemical composition

3.2.1 Pipes are to be manufactured by the electric resistance or induction welding process and, if required, may be subsequently hot reduced or cold finished.

3.2.2 Where it is proposed to use other welding processes, details of the welding processes and procedures are to be submitted for review.

3.2.3 In all cases, welding procedure tests are required. Test samples are to be subjected to the same heat treatment as the pipe.

3.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.3.1.

3.3 Heat treatment

3.3.1 Pipes are to be supplied in the heat treated condition given in Table 6.3.3.

3.4 Mechanical tests

3.4.1 All pipes are to be presented in batches as defined in Section 1.

3.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

3.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.3.2.

3.5 Mechanical properties for design

3.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460 and 1Cr½Mo steel can be taken from the appropriate Tables in Section 2.

Table 6.3.1 Chemical composition of welded pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %										
			C	Si	Mn	S max.	P max.	Residual elements					
Carbon and carbon-manganese	320	Any method (see Note)	≤0,16	—	0,30–0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.					
	360		≤0,17	≤0,35	0,40–1,00	0,045	0,045						
	410	Killed	≤0,21	≤0,35	0,40–1,20	0,045	0,045						
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045						
								Ni	Cr	Mo	Cu	Sn	Al
1Cr½Mo	440	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30 max.	0,70–1,10	0,45–0,65	0,25 max.	0,03 max.	≤0,020

NOTE
For rimming steels, the carbon content may be increased to 0,19% max.

Table 6.3.2 Mechanical properties for acceptance purposes: welded pressure pipes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*
Carbon and carbon-manganese	320 360 410 460	195 215 235 265	320 – 440 360 – 480 410 – 530 460 – 580	25 24 22 21	0,10 0,10 0,08 0,07
1Cr$^1/_2$Mo	440	275	440 – 590	22	0,07

Table 6.3.3 Heat treatment: welded pressure pipes

Type of steel	Condition of supply
Carbon and carbon-manganese, *see* Note	Normalized (Normalized and tempered at the option of the manufacturer)
1Cr$^1/_2$Mo	Normalized and tempered

NOTE
Subject to special approval, electric resistance welded (ERW) pipes and tubes in grades 320 and 360 may be supplied without heat treatment for the following applications:
(a) Class 2 piping systems, except for liquefied gases or other low temperature applications.
(b) Class 3 piping systems.

■ *Section 4* Ferritic steel pressure pipes for low temperature service

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and nickel pipes intended for use in the piping arrangements for liquefied gases where the design temperature is less than 0°C. These requirements are also applicable for other types of pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

4.2 Manufacture and chemical composition

4.2.1 Carbon and carbon-manganese steel pipes are to be manufactured by a seamless, electric resistance or induction welding process.

4.2.2 Nickel steel pipes are to be manufactured by a seamless process.

4.2.3 Seamless pipes may be hot finished or cold finished. Welded pipes may be as-welded, hot finished or cold finished. The terms 'hot finished', 'cold finished' and 'as-welded' apply to the condition of the pipes before final heat treatment.

4.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.4.1.

4.3 Heat treatment

4.3.1 Pipes are to be supplied in the condition given in Table 6.4.3.

4.4 Mechanical tests

4.4.1 All pipes are to be presented for test in batches as defined in Section 1 for Class 1 pressure piping systems, but in addition the material in each batch is to be from the same cast.

4.4.2 At least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests.

4.4.3 Each pressure pipe selected for test is to be subjected to tensile, flattening or bend test at room temperature and, where the wall thickness is 6 mm or greater, an impact test at the test temperature specified in Table 6.4.2.

4.4.4 The impact tests are to consist of a set of three Charpy V-notch test specimens cut in the longitudinal direction with the notch perpendicular to the original surface of the pipe. The dimensions of the test specimens are to be in accordance with the requirements of Chapter 2.

4.4.5 The results of all tensile, flattening and bend tests are to comply with the appropriate values in Table 6.4.2.

4.4.6 The average value for impact test specimens is to comply with the appropriate requirements of Table 6.4.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4.1 for re-test procedures.

Table 6.4.1 Chemical composition

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle sample %							
			C max.	Si	Mn	P max.	S max.	Ni	Al_{sol} *see* Note	Residual elements
Carbon	360	Fully killed	0,17	0,10—0,35	0,40—1,00	0,030	0,025	—	0,015 min.	Cr 0,25 Cu 0,30 Mo 0,10 Ni 0,30 Total 0,70
Carbon-manganese	410 and 460		0,20	0,10—0,35	0,60—1,40	0,030	0,025	—	0,015 min.	
$3^{1}/_{2}$Ni	440		0,15	0,15—0,35	0,30—0,90	0,025	0,020	3,25—3,75	—	Cr 0,25 Cu 0,30 Mo 0,10 Total 0,60
9Ni	690		0,13	0,15—0,30	0,30—0,90	0,025	0,020	8,50—9,50	—	

NOTE
Where a minimum Al_{sol} of 0,015% is specified, the determination of the total aluminium is acceptable provided that the result is not less than 0,020%.

Table 6.4.2 Mechanical properties for acceptance purposes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)	Charpy V-notch impact tests	
							Test temperature °C	Average energy J minimum
Carbon	360	210	360—480	24	0,10	4*t*	–40	27
Carbon-manganese	410 460	235 260	410—530 460—580	22 21	0,08 0,07	4*t*	–50	27
$3^{1}/_{2}$Ni	440	245	440—590	16	0,08	4*t*	–95	34
9Ni	690	510	690—840	15	0,08	4*t*	–196	41

For standard subsidiary impact test specimens, the minimum energy values are to be as follows:

Required average energy value for standard 10 mm x 10 mm	Subsidiary 10 mm x 7,5 mm	Subsidiary 10 mm x 5 mm
	Average energy	Average energy
27 J	22 J	18 J
34 J	28 J	23 J
41 J	34 J	27 J

Table 6.4.3 Heat treatment

Type of steel	Condition of supply
Carbon and carbon-manganese	Hot finished Normalized Normalized and tempered
$3^{1}/_{2}$ Ni	Normalized Normalized and tempered
9Ni	Double normalized and tempered Quenched and tempered

Section 5
Austenitic stainless steel pressure pipes

5.1 Scope

5.1.1 Provision is made in this Section for austenitic stainless steel pipes suitable for use in the construction of the piping systems for chemicals and for liquefied gases where the design temperature is not less than minus 165°C and for bulk chemical tankers.

5.1.2 Austenitic stainless steels are also suitable for service at elevated temperatures. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

5.1.3 Where it is intended to supply seamless pipes in the direct quenched condition, a programme of tests for approval is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR, *see* Ch 1,2.2.

5.2 Manufacture and chemical composition

5.2.1 Pipes are to be manufactured by a seamless or a continuous automatic electric fusion welding process.

5.2.2 Welding is to be in a longitudinal direction, with or without the addition of filler metal.

5.2.3 The chemical composition of the ladle samples is to comply with the appropriate requirements of Table 6.5.1.

5.3 Heat treatment

5.3.1 Pipes are generally to be supplied by the manufacturer in the solution treated condition over their full length.

5.3.2 Alternatively, seamless pipes may be direct quenched immediately after hot forming, while the temperature of the pipes is not less than the specified minimum solution treatment temperature.

5.4 Mechanical tests

5.4.1 All pipes are to be presented in batches as defined in Section 1 for Class I and II piping systems.

5.4.2 Each pipe selected for test is to be subjected to tensile and flattening or bend tests.

5.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.5.2.

Table 6.5.1 Chemical composition

Type of steel	Grade	Chemical composition of ladle sample %								
		C max.	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others
304L	490	0,03	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	—
316L	490	0,03	<1,00	<2,00	0,045	0,030	16,0 – 18,5	2,0–3,0	11,0 – 14,5	—
321	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Ti ≥5 x C ≤0,80
347	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Nb ≥10 x C ≤1,00

Table 6.5.2 Mechanical properties for acceptance purposes

Type of steel	Grade	0,2% proof stress N/mm^2 (*see* Note)	1,0% proof stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)
304L	490	175	205	490 – 690	30	0,09	3*t*
316L	490	185	215	490 – 690	30	0,09	3*t*
321	510	195	235	510 – 710	30	0,09	3*t*
347	510	205	245	510 – 710	30	0,09	3*t*

NOTE
The 0,2% proof stress values given for information purposes and unless otherwise agreed are not required to be verified by test.

5.5 Intergranular corrosion tests

5.5.1 For materials used for piping systems for chemicals, intercrystalline corrosion tests are to be carried out on one per cent of the number of pipes in each batch, with a minimum of one pipe.

5.5.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases, the total surface area is to be between 15 and 35 cm^2.

5.5.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be in accordance with Ch 2,8.

5.5.4 After immersion, the full cross-section test specimens are to be subjected to a flattening test in accordance with the requirements of Chapter 2. The strip test specimens are to be subjected to a bend test through 90° over a mandrel of diameter equal to twice the thickness of the test specimen.

5.6 Fabricated pipework

5.6.1 Fabricated pipework is to be produced from material manufactured in accordance with 5.2, 5.3, 5.4 and 5.5.

5.6.2 Welding is to be carried out in accordance with an approved and qualified procedure by suitably qualified welders.

5.6.3 Fabricated pipework may be supplied in the as-welded condition without subsequent solution treatment provided that welding procedure tests have demonstrated satisfactory material properties including resistance to intercrystalline corrosion.

5.6.4 In addition, butt welds are to be subjected to 5 per cent radiographic examination for Class I, and 2 per cent for Class II pipes.

5.6.5 Fabricated pipework in the as-welded condition and intended for systems located on deck is to be protected by a suitable corrosion control coating.

■ *Section 6* Boiler and superheater tubes

6.1 Scope

6.1.1 Provision is made in this Section for boiler and superheater tubes in carbon, carbon-manganese and low alloy steels.

6.1.2 Austenitic stainless steels may also be used for this type of service. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

6.2 Manufacture and chemical composition

6.2.1 Tubes are to be seamless or welded and are to be manufactured in accordance with the requirements of Sections 2 and 3, respectively.

6.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 6.2.1 or 6.3.1, as appropriate.

6.3 Heat treatment

6.3.1 All tubes are to be supplied in accordance with the requirements given in Table 6.2.3 or 6.3.3 as appropriate, except that 1Cr$^1/_2$Mo steel may be supplied in the normalized only condition when the carbon content does not exceed 0,15 per cent.

6.4 Mechanical tests

6.4.1 Tubes are to be presented for test in batches as defined in Section 1.

6.4.2 Each boiler and superheater tube selected for test is to be subjected to at least the following:
(a) Tensile test.
(b) Flattening or bending test.
(c) Expanding or flanging test.

6.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.6.1.

6.5 Mechanical properties for design

6.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460, 1Cr$^1/_2$Mo and 2$^1/_4$Cr1Mo steels can be taken from the appropriate Tables in Section 2.

6.5.2 Where rimming steel is used, the design temperature is limited to 400°C.

Table 6.6.1 Mechanical properties for acceptance purposes: boiler and superheater tubes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)	Drift expanding and flanging test minimum % increase in outside diameter		
							Ratio $\frac{\text{Inside diameter}}{\text{Outside diameter}}$		
							≤0,6	>0,6 ≤0,8	>0,8
Carbon and carbon-manganese	320 360 410 460	195 215 235 265	320–440 360–480 410–530 460–580	25 24 22 21	0,10 0,10 0,08 0,07	4*t*	12 12 10 8	15 15 12 10	19 19 17 15
1Cr$^1/_2$Mo	440	275	440–590	22	0,07	4*t*	8	10	15
2$^1/_2$Cr1Mo	410 (*see* Note 1) 490 (*see* Note 2)	135 275	410–560 490–640	20 16	0,07	4*t*	8	10	15

NOTES
1. Annealed condition.
2. Normalized and tempered condition.

Section

Section 1 General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for both grey (flake) and spheroidal (nodular) graphite iron castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the requirements given in this Section and either Section 2 for grey iron castings or Section 3 for spheroidal graphite iron castings. Castings for crankshafts are additionally to comply with the requirements detailed in Section 4.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted, provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.2, may be adopted subject to approval by Lloyd's Register (hereinafter referred to as 'LR').

1.2 Manufacture

1.2.1 Castings as designated in 1.1.2 are to be made at foundries approved by LR.

1.2.2 Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

1.3 Quality of castings

1.3.1 Castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

1.4 Chemical composition

1.4.1 The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings.

1.5 Heat treatment

1.5.1 Except as required by 1.5.2, castings may be supplied in either the as cast or heat treated condition.

1.5.2 For some applications, such as elevated temperature service, or where dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining.

1.5.3 Where spheroidal graphite iron castings are to be impact tested they should be suitably ferritized, *see* 3.3.2.

1.5.4 Where it is proposed to carry out local hardening of the surface of a casting, full details of the proposed procedure are to be submitted for approval.

1.6 Test material

1.6.1 At least one test sample is to be provided for each casting or batch of castings. For large castings, where more than one ladle of metal is used, one test sample is to be provided, from each ladle used.

1.6.2 A batch testing procedure may be adopted for castings with a fettled mass of 1 tonne or less. All castings in a batch are to be of similar type and dimensions, and cast from the same ladle of metal. One test sample is to be provided for each multiple of two tonnes of fettled castings in the batch.

1.6.3 Where separately cast test samples are used, they are to be cast in moulds made from the same type of material as used for the castings and are not to be stripped from the moulds until the temperature is below 500°C.

1.6.4 All test samples are to be suitably marked to identify them with the castings which they represent.

1.6.5 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

1.7 Mechanical tests

1.7.1 One tensile specimen is to be prepared from each test sample. The dimensions of the test specimens and the testing procedures used are to be in accordance with Chapter 2.

1.7.2 The results of all tensile tests are to comply with the requirements given in Section 2, 3 or 4, as appropriate.

1.7.3 In the case of castings supplied in the as cast condition which initially do not meet the requirements of 1.7.2, the manufacturer, by agreement with the purchaser, has the right to heat treat the castings, together with the representative test samples, and re-submit them for acceptance.

1.7.4 In the case of a batch of castings supplied in the heat treated condition which initially do not meet the requirements of 1.7.2, the manufacturer has the right to re-heat treat the batch together with the representative test samples, and re-submit the castings for acceptance. The number of reheat treatments and retestings will be restricted to two.

1.8 Visual and non-destructive examination

1.8.1 All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.8.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

1.8.3 All castings are to be presented to the Surveyor for visual examination and this is to include the examination of internal surfaces where applicable.

1.8.4 The non-destructive examination of castings is not required unless otherwise stated in the approved plan or where there is reason to suspect the soundness of the casting.

1.8.5 In the event of any casting proving defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.9 Rectification of defective castings

1.9.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

1.9.2 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by vacuum impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

1.9.3 Repairs by welding are generally not permitted, but may be considered in special circumstances. In such cases, full details of the proposed repair procedure are to be submitted for approval prior to the commencement of the proposed rectification.

1.10 Pressure testing

1.10.1 When required by the relevant Rules, castings are to be pressure tested before final acceptance. These tests are to be carried out in the presence and to the satisfaction of the Surveyor.

1.11 Identification of castings

1.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the castings when required.

1.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:
(a) Type and grade of cast iron.
(b) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(c) Manufacturer's name or trade mark.
(d) LR or Lloyd's Register and the abbreviated name of LR's local office.
(e) Personal stamp of Surveyor responsible for inspection.
(f) Test pressure, where applicable.
(g) Date of final inspection.

1.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.12 Certification

1.12.1 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:
(a) Purchaser's name and order number.
(b) Description of castings and quality of cast iron.
(c) Identification number.
(d) General details of heat treatment, where applicable.
(e) Results of mechanical tests.
(f) Test pressure, where applicable.
(g) When specially required, the chemical analysis of ladle samples.

■ *Section 2* Grey iron castings

2.1 Scope

2.1.1 This Section gives the specific requirements for grey cast iron castings.

2.2 Test material

2.2.1 Separately cast test samples in the form of cylindrical bars, 30 mm diameter and of a suitable length, are to be used unless otherwise agreed by LR. Test samples of other dimensions may be specially required for some components as may cast-on samples. In these circumstances, the tensile strength requirements are to be agreed.

2.2.2 When two or more test samples are cast simultaneously in a single mould, the bars are to be at least 50 mm apart.

2.2.3 Test samples may be cast integrally when a casting is both more than 20 mm thick and its mass exceeds 200 kg, subject to agreement between the manufacturer and the purchaser. The type and location of the samples are to be such as to provide approximately the same cooling conditions as for the casting it represents and are also subject to agreement.

2.2.4 For continuous melting of the same grade of cast iron in large tonnages the mass of a batch may be taken as the output of two hours of pouring.

2.2.5 Where 2.2.4 applies and production is carefully monitored by systematic checking of the melting process by, for example, chill testing, chemical analysis or thermal analysis, test samples may be taken at longer intervals as agreed by the Surveyor.

2.3 Mechanical tests

2.3.1 Only the tensile strength is to be determined, and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. Except for crankshaft castings (*see* Section 4), the specified tensile strength is to be not less than 200 N/mm^2 and not more than 450 N/mm^2. The fractured surfaces of all tensile test specimens are to be granular and entirely grey in appearance.

■ *Section 3* Spheroidal or nodular graphite iron castings

3.1 Scope

3.1.1 This Section gives the specific requirements for spheroidal or nodular graphite iron castings.

3.1.2 These requirements are generally applicable to castings intended for use at ambient temperatures. Additional requirements will be necessary when the castings are intended for service at either low or elevated temperatures. Impact test requirements are given for low temperature service in 3.3.2.

3.2 Test material

3.2.1 The test samples are to be as detailed in Figs. 7.3.1 or 7.3.2. The dimensions of the test specimens and testing procedures used are to be in accordance with Chapter 2. Test samples of other dimensions may be specially required for some castings and these are to be agreed with the Surveyor.

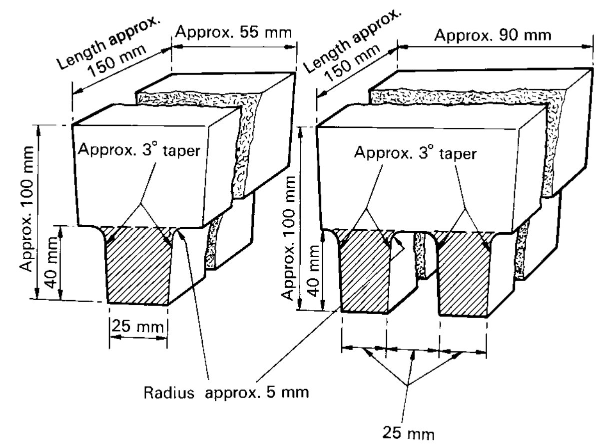


Fig. 7.3.1 U-type test samples

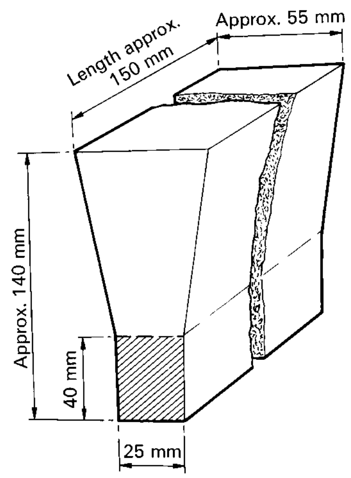


Fig. 7.3.2 Y-type test samples

3.2.2 The test samples may be either gated to the casting or separately cast.

3.2.3 Where separately cast test samples are used, they are to be taken towards the end of pouring of the castings.

3.3 Mechanical tests

3.3.1 The tensile strength and elongation are to be determined and are to comply with the requirements of Table 7.3.1. Minimum values for the 0,2 per cent proof stress are also included in this Table but are to be determined only if included in the specification. Typical ranges of hardness values are also given in Table 7.3.1 and are intended for information purposes.

3.3.2 Impact tests may be required for some applications in which case the selection of the grade is to be confined to those listed in Table 7.3.2. These castings are to be given a ferritizing heat treatment. The mechanical test results are to comply with Table 7.3.2.

3.4 Metallographic examination

3.4.1 Samples for metallographic examination are to be prepared for spheroidal or nodular graphite iron castings. These samples are to be representative of each ladle used and may conveniently be taken from the tensile test specimens. Alternative arrangements for the provision of these samples may, however, be adopted subject to the concurrence of the Surveyor. They are, however, to be taken towards the end of the pour.

3.4.2 Examination of the samples is to show that at least 90 per cent of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in Table 7.3.1 and are intended for information purposes.

Table 7.3.1 Mechanical properties for acceptance purposes: spheroidal or nodular graphite iron castings

Specified minimum tensile strength N/mm^2	0,2% proof stress (*see* Note) N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Typical hardness value HB (*see* 3.3.1)	Typical structure of matrix (*see* 3.4.1)
370	230	17	120 – 180	Ferrite
400	250	12	140 – 200	Ferrite
500	320	7	170 – 240	Ferrite/pearlite
600	370	3	190 – 270	Pearlite/ferrite
700	420	2	230 – 300	Pearlite
800	480	2	250 – 350	Pearlite or tempered structure

NOTE
If required, intermediate values may be calculated by linear interpolation.

Table 7.3.2 Mechanical properties: impact tested grades

Specified minimum tensile strength N/mm^2	0,2% proof stress minimum (*See* Note 1) N/mm^2	Elongation on $5,65\sqrt{S_o}$ minimum %	Typical hardness value	Charpy V-notch impact tests	
				Test temperature °C (*See* Note 2)	Average energy J minimum
350	220	22	110 – 170	20 –40	17 12
400	250	18	140 – 200	20 –20	14 12

NOTES
1. Proof stresses need only be determined if included in the specification.
2. Tests need only be made at either of the temperatures listed, as appropriate.

Section 4
Iron castings for crankshafts

4.1 Scope

4.1.1 This Section gives additional requirements for cast iron crankshafts intended for diesel engines and compressors. For both of these applications, details of the proposed specification are to be submitted for approval.

4.1.2 Crankshaft castings in grey iron are acceptable only for compressors, and the specified minimum tensile strength is to be not less than 300 N/mm^2.

4.1.3 For crankshaft castings in spheroidal or nodular graphite iron, the specified minimum tensile strength is to be not less than 370 N/mm^2.

4.2 Manufacture

4.2.1 Details of the method of manufacture, including the arrangements proposed for the provision of test material, are to be submitted for approval.

4.2.2 Tests to demonstrate the soundness of prototype castings and the mechanical properties at important locations will be required.

4.3 Heat treatment

4.3.1 In general, crankshaft castings other than those which are fully annealed, normalized or oil quenched and tempered, are to receive a suitable stress relief heat treatment before machining.

4.3.2 Where it is proposed to harden the surfaces of machined pins and/or journals of cast iron crankshafts, details of the process are to be submitted for approval. Before such a process is applied to a crankshaft it is to be demonstrated by procedure tests, and to the satisfaction of the Surveyor, that the process is suitably controlled and does not impair the strength or soundness of the material.

4.4 Test material

4.4.1 Unless otherwise approved, the dimensions of the test samples are to be such as to ensure that they have mechanical properties representative of those of the average section of the crankshaft casting.

4.4.2 For large crankshaft castings, the test samples are to be cast integral with, or gated from, each casting.

4.4.3 The batch testing procedure detailed in 1.6.2 may be adopted only where small and identical crankshaft castings are produced in quantity. Generally, the fettled mass of each casting in a batch is not to exceed 100 kg, and in addition to tensile tests, the hardness of each casting is to be determined. For this purpose, a small flat is to be ground on each crankshaft, and Brinell hardness tests are to be carried out. The results obtained from these tests are to comply with the approved specification.

4.5 Non-destructive examination

4.5.1 Cast crankshafts are to be subjected to a full magnetic particle or dye penetrant examination after final machining and completion of any surface hardening operations.

4.5.2 Particular attention is to be given to the testing of the pins, journals and associated fillet radii.

4.5.3 Cracks and crack-like defects are not acceptable. Fillet radii are to be free from any indications.

4.6 Rectification of defective castings

4.6.1 Cast iron crankshafts are not to be repaired by welding, and blemishes are not to be plugged with a filler.

4.7 Certification

4.7.1 The chemical composition of ladle samples is to be given in addition to the other particulars detailed in 1.12.1.

Section

■ *Section 1* Plates, bars and sections

1.1 Scope

1.1.1 This Section makes provision for aluminium alloy plates, bars and sections intended for use in the construction of ships and other marine structures and for cryogenic applications.

1.1.2 Except as provided in 1.1.3, all items are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and those detailed in this Section.

1.1.3 Plates less than 3,0 mm thick and sections less than 40 mm x 40 mm x 3,0 mm may be manufactured and tested in accordance with the requirements of an acceptable National specification.

1.1.4 Materials intended for the construction of cargo tanks or storage for liquefied gases, and for other low temperature applications, are to be manufactured in the 5083 alloy in the annealed condition.

1.1.5 As an alternative to 1.1.2 and 1.1.4, materials which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section and are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 Aluminium alloys are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The alloys may be cast either in ingot moulds or by an approved continuous casting process. Plates are to be formed by rolling and may be hot or cold finished. Bars and sections may be formed by extrusion, rolling or drawing.

1.2.3 All melts are to be suitably degassed prior to casting such that the aim hydrogen content is less than 0,2 ml per 100 g.

1.3 Quality of materials

1.3.1 Materials are to be free from surface or internal defects of such a nature as would be harmful in service.

1.3.2 The manufacturer is to verify the integrity of pressure welds of closed extrusion profiles in accordance with 1.10.

1.4 Dimensional tolerances

1.4.1 Underthickness tolerances for rolled products for marine construction are given in Table 8.1.1.

Table 8.1.1 Underthickness tolerances for rolled products for marine construction

Nominal thickness range, mm	Underthickness tolerance for nominal width range, mm		
	≤1500	>1500 ≤2000	>2000 ≤3500
≥3,0 <4,0	0,10	0,15	0,15
≥4,0 <8,0	0,20	0,20	0,25
≥8,0 <12	0,25	0,25	0,25
≥12 <20	0,35	0,40	0,50
≥20 <50	0,45	0,50	0,65

1.4.2 Underthickness tolerances for extruded products for marine construction are given in Table 8.1.2.

Table 8.1.2 Underthickness tolerances for extrusions for marine construction

Nominal thickness range, mm	Open profiles, sections circumscribed by a circle of diameter, mm			Closed profiles
	≤250	>250 ≤400	>400	
≥3,0 <6,0	0,25	0,35	0,40	0,25
≥6,0 <50	0,30	0,40	0,45	0,30

1.4.3 There are to be no underthickness tolerances for materials for application in cryogenic process pressure vessels.

1.4.4 Dimensional tolerances other than permitted underthicknesses are to comply with an acceptable National or International Standard.

1.5 Chemical composition

1.5.1 Samples for chemical analysis are to be taken representative of each cast, or the equivalent where a continuous melting process is involved.

1.5.2 The chemical composition of these samples is to comply with the requirements of Table 8.1.3.

1.6 Heat treatment

1.6.1 The Aluminium 5000 series alloys, capable of being strain hardened, are to be supplied in any of the following temper conditions:

- O annealed
- H111 annealed with slight strain hardening
- H112 strain hardened from working at elevated temperatures
- H116 strain hardened and with specified resistance to exfoliation corrosion for alloys where the magnesium content is 4 per cent or more
- H321 strain hardened and stabilized.

1.6.2 The H116 temper is specially developed for use in a marine environment.

1.6.3 The Aluminium 6000 series alloys, capable of being age hardened, are to be supplied in either of the following temper conditions:

- T5 hot worked and artificially aged
- T6 solution treated and artificially aged.

1.7 Test material

1.7.1 Materials of the same product form, (i.e. plates, sections or bars) and thickness and from a single cast or equivalent, are to be presented for test in batches of not more than 2 tonnes, with the exceptions of those given in 1.7.2, 1.7.3 and 1.7.4.

1.7.2 For single plates or coils weighing more than 2 tonnes, only one tensile specimen per plate or coil is to be taken.

1.7.3 A tensile test specimen is required from each plate to be used in the construction of cargo tanks, secondary barriers and process pressure vessels with design temperatures below –55°C.

1.7.4 Extrusions, bars and sections of less than 1 kg/m in nominal weight are to be tested in batches of 1 tonne. Where the nominal weight is greater than 5 kg/m, one tensile test is to be carried out for every three tonnes produced, or fractions thereof.

1.7.5 If the material is supplied in the heat treated condition, each batch is to be treated in the same furnace charge or subjected to the same finishing treatment when a continuous furnace is used.

1.7.6 For plates over 300 mm in width, tensile test specimens are to be cut with their length transverse to the principal direction of rolling. For narrow plates and for sections and bars, the test specimens are to be cut in the longitudinal direction. Longitudinal tensile test specimens are accepted for the strain hardenable 5000 series alloys.

Table 8.1.3 Chemical composition, percentage

Element	5083	5383	5059	5086	5754	5456	6005–A (*see* Note 1)	6061 (*see* Note 1)	6082
Copper	0,10 max.	0,10 max.	0,25 max.	0,10 max.	0,10 max.	0,10 max.	0,30 max.	0,15—0,40	0,10 max.
Magnesium	4,0—4,9	4,0—4,9	5,0—6,0	3,5—4,5	2,6—3,6	4,7—5,5	0,40—0,70	0,80—1,20	0,60—1,20
Silicon	0,40 max.	0,25 max.	0,45 max.	0,40 max.	0,40 max.	0,25 max.	0,50—0,90	0,40—0,80	0,70—1,30
Iron	0,40 max.	0,25 max.	0,50 max.	0,50 max.	0,40 max.	0,40 max.	0,35 max.	0,70 max.	0,50 max.
Manganese	0,40—1,00	0,7—1,0	0,6—1,2	0,20—0,70	0,50 max. (*see* Note 2)	0,50—1,00	0,50 max. (*see* Note 3)	0,15 max.	0,40—1,00
Zinc	0,25 max.	0,25 max.	0,40—0,90	0,25 max.	0,20 max.	0,25 max.	0,20 max.	0,25 max.	0,20 max.
Chromium	0,05—0,25	0,05—0,25	0,25 max.	0,05—0,25	0,30 max. (*see* Note 2)	0,05—0,20	0,30 max. (*see* Note 3)	0,04—0,35	0,25 max.
Titanium	0,15 max.	0,15 max.	0,20 max.	0,15 max.	0,15 max.	0,20 max.	0,10 max.	0,15 max.	0,10 max.
Zirconium		0,02 max.	0,05—0,25						
Other elements: each	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. Mn + Cr = 0,10 min., 0,60 max.
3. Mn + Cr = 0,12 min., 0,50 max.

Table 8.1.4 Minimum mechanical properties for acceptance purposes of selected rolled aluminium alloys

Alloy and temper condition	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m, N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ %	Elongation on 5*d* %
5083-0/H111	≤12,5	125	275-350	16	
	>12,5	125	275-350		15
5083–H112	≤12,5	125	275	12	
	>12,5	125	275		10
5083–H116	≤12,5	215	305	12 (*see* Note 1)	
	>12,5	215	305		10
5083–H321	≤12,5	215-295	305-380	10 (*see* Note 2)	
	>12,5	215-295	305-380		9
5383–0/H111	3 ≤ t ≤ 50	145	290		17
5383–H116 or H321	3 ≤ t ≤ 50	220	305		10
5086–0/H111	≤12,5	100	240-310	17	
	>12,5	100	240-310		16
5086–H112	≤12,5	125	250	8	
	>12,5	105	240		9
5086–H116	≤12,5	195	275	10	
	>12,5	195	275		9
5086–H321	≤12,5	185	275-335	10	
	>12,5	185	275-335		9
5059–0/H111	3 ≤ t ≤ 50	160	330		24
5059–H116 or H321	3 ≤ t ≤ 50	270 (*see* Note 3)	370 (*see* Note 3)		10
5456–0	≤12,5	130-205	290-365	16	
	>12,5	125-205	285-360		14
5456–H116	≤12,5	230	315	10	
	>12,5	200	290		10
5456–H321	≤12,5	230-315	315-405	12	
	>12,5	215-305	305-385		10
5754–0/H111	≤12,5	80	190	18	
	>12,5	80	190		17
6061–T5/T6		240	290		10
6082–T5/T6		240	280		8

NOTES
1. 10% for thickness up to and including 6,0 mm.
2. 8% for thickness up to and including 6,0 mm.
3. Yield strength minimum 260 N/mm^2 and tensile strength minimum 360 N/mm^2 for thickness exceeding 20 mm.

1.7.7 Longitudinal tensile test specimens from a plate are to be taken at 1/3 width from the longitudinal edge. Longitudinal tensile test specimens taken from extruded sections should be taken in the range from 1/3 to 1/2 of the distance from the edge to the centre of the thickest region of the section.

1.8 Mechanical tests

1.8.1 At least one tensile test specimen is to be prepared from each batch of material submitted for acceptance.

1.8.2 Tensile test specimens are to be machined to the dimensions given in Fig. 2.2.3 in Chapter 2. Alternatively, machined proportional test specimens of circular cross-section in accordance with Fig. 2.2.2 in Chapter 2 may be used provided that the diameter is not less than 10 mm. Round bars may be tested in full section, or test specimens may be machined in accordance with the dimensions given in Fig. 2.2.2 in Chapter 2.

1.8.3 The results of all tensile tests are to comply with the values given in Tables 8.1.4 to 8.1.6, as applicable.

Table 8.1.5 Minimum mechanical properties for acceptance purposes of selected open profile extruded aluminium alloys

Alloy and temper condition	0,2% proof stress N/mm^2	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ %
6005A–T5/T6	215	260	6
6061–T5/T6	240	260	8
6082–T5/T6	260	310	8

NOTE
Values cover thicknesses up to and including 50 mm; thickness above 50 mm will be subject to special consideration.

Table 8.1.6 Minimum mechanical properties for acceptance purposes of selected closed profile extruded aluminium alloys

Alloy and temper condition	0,2% proof stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ %
6005A–T5/T6	215	250	5
6061–T5/T6	205	245	4
6082–T5/T6	240	290	5
NOTE Values cover thicknesses up to and including 50 mm; thickness above 50 mm will be subject to special consideration.			

1.9 Corrosion tests

1.9.1 Rolled 5000 series alloys of type 5083, 5383, 5059, 5456 and 5086 in the H116 and H321 tempers intended for use in marine hull construction or in marine applications with frequent direct contact with seawater are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance.

1.9.2 The manufacturer is to establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x, is to be prepared for each of the alloy-tempers and thickness ranges relevant. The reference photographs are to be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET).The samples are also to have exhibited resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2, when subjected to the test described in ASTM G67. Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by LR. Production practices are not to be changed after approval of the reference micrographs. For batch acceptance of 5000 series alloys in the H116 and H321 tempers for use in direct contact with seawater, metallographic examination of one sample selected from mid width at one end of a randomly selected plate is to be carried out. The microstructure of the sample is to be compared to an approved reference photomicrograph of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface shall be prepared for metallographic examination. If the microstructure shows evidence of continuous grain boundary networks of aluminium-magnesium precipitate in excess of the approved reference photomicrographs, the batch is either to be rejected or tested for exfoliation corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards.

1.9.3 For batch acceptance of 5000 series alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate is to be carried out. The microstructure of the sample is to be compared to the reference photomicrograph of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface is to be prepared for metallographic examination. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. If the results from testing satisfy the acceptance criteria stated in 1.9.2 the batch is accepted, otherwise it is to be rejected.

1.9.4 As an alternative to metallographic examination, each batch may be tested for exfoliation corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 or equivalent standards.

1.9.5 Tempers that are corrosion tested in accordance with 1.9.3 are to be marked ‘M’ after the temper condition, e.g. 5083 H321 M.

1.10 Pressure weld tests

1.10.1 The integrity of pressure welds of closed profile extrusions is to be verified by examination of macrosections or drift expansion tests.

1.10.2 Every closed profile extrusion is to be sampled, except where the closed profile extrusions are equal to or shorter than 6,0 m long, in which case a batch is to comprise five profiles. Every sample is to be tested at both ends.

1.10.3 Where verification is by examination of macrosections, no indication of lack of fusion is permitted.

1.10.4 Where verification of fusion at pressure welds of closed profile extrusions is by drift expansion test, testing is to be generally in accordance with 4.3.4 and 4.3.5 and Fig. 2.4.1 in Chapter 2. The minimum included angle of the mandrel is to be 60°, and the minimum specimen length, 50 mm. For acceptance, there is to be no failure by a clean split along the weld line.

1.11 Visual and non-destructive examination

1.11.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer, and acceptance by the Surveyors of material later found to be defective shall not absolve the manufacturer from this responsibility.

1.11.2 In general, the non-destructive examination of materials is not required for acceptance purposes. Manufacturers are expected, however, to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

1.11.3 For applications where the non-destructive examination of materials is considered to be necessary, the extent of this examination, together with appropriate acceptance standards, are to be agreed between the purchaser, manufacturer and Surveyor.

1.12 Rectification of defects

1.12.1 Slight surface imperfections may be removed by mechanical means, provided that the prior agreement of the Surveyor is obtained, that the work is carried out to his satisfaction and that the final dimensions are acceptable. The repair of defects by welding is not allowed.

1.13 Identification

1.13.1 The manufacturer is to adopt a system of identification which will ensure that all finished material in a batch presented for test is of the same nominal chemical composition.

1.13.2 Products are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:
(a) Manufacturer's name or trade mark.
(b) Alloy grade and temper condition.
(c) Identification mark which will enable the full history of the item to be traced.
(d) The stamp of the LR brand, .

1.14 Certification

1.14.1 The manufacturer's test certificate can be accepted provided it has been stamped and endorsed by the Surveyor.

1.14.2 Each test certificate or shipping statement is to include the following particulars:
(a) Purchaser's name and order number.
(b) Contract number.
(c) Address to which material is to be despatched.
(d) Description and dimensions.
(e) Alloy grade and temper condition.
(f) Identification mark which will enable the full history of the item to be traced.
(g) Chemical composition.
(h) Mechanical test results (not required on shipping statement).
(j) Details of heat treatment, where applicable.

1.14.3 Where the alloy is not produced at the works at which it is wrought, a certificate is to be supplied by the manufacturer of the alloy stating the cast number and chemical composition. The works at which the alloy was produced must be approved by LR.

■ *Section 2* Aluminium alloy rivets

2.1 Scope

2.1.1 Provision is made in this Section for aluminium alloy rivets intended for use in the construction of marine structures.

2.1.2 They are to be manufactured and tested in accordance with the appropriate requirements of Section 1 and those detailed in this Section.

2.2 Chemical composition

2.2.1 The chemical composition of bars used for the manufacture of rivets is to comply with the requirements of Table 8.2.1.

Table 8.2.1 Chemical composition, percentage

Element	5154A	6082
Copper	0,10 max.	0,10 max.
Magnesium	3,1 – 3,9	0,6 – 1,2
Silicon	0,50 max.	0,7 – 1,3
Iron	0,50 max.	0,50 max.
Manganese	0,1 – 0,5	0,4 – 1,0
Zinc	0,20 max.	0,20 max.
Chromium	0,25 max.	0,25 max.
Titanium	0,20 max.	0,10 max.
Other elements: each	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.
Aluminium	Remainder	Remainder

2.3 Heat treatment

2.3.1 Rivets are to be supplied in the following condition:
5154A – annealed
6082 – solution treated.

2.4 Test material

2.4.1 Bars intended for the manufacture of rivets are to be presented for test in batches of not more than 250 kg. The material in each batch is to be the same diameter and nominal chemical composition.

2.4.2 At least one test sample is to be selected from each batch and, prior to testing, is to be heat treated in full cross-section and in a manner simulating the heat treatment applied to the finished rivets.

2.5 Mechanical tests

2.5.1 At least one tensile and one dump test specimen are to be prepared from each test sample.

2.5.2 The tensile test specimen may be either a suitable length of bar tested in full cross-section or a specimen machined to the dimensions given in Fig. 2.2.2 in Chapter 2.

2.5.3 The dump test specimen is to consist of a section cut from the bar with the ends perpendicular to the axis. The length of this section is to be equal to the diameter of the bar.

2.5.4 The results of tensile tests are to comply with the appropriate requirements of Table 8.2.2.

Table 8.2.2 Mechanical properties for acceptance purposes

Mechanical properties	5154A	6082
0,2% proof stress N/mm^2 min.	90	120
Tensile strength N/mm^2 min.	220	190
Elongation on $5{,}65\sqrt{S_0}$ % min.	18	16

2.5.5 The dump test is to be carried out at ambient temperature and is to consist of compressing the specimen until the diameter is increased to 1,6 times the original diameter. After compression, the specimen is to be free from cracks.

2.6 Tests from manufactured rivets

2.6.1 At least three samples are to be selected from each consignment of manufactured rivets. Dump tests as detailed in 2.5 are to be carried out on each sample.

2.7 Identification

2.7.1 Each package of manufactured rivets is to be identified with attached labels giving the following details:
(a) Manufacturer's name or trade mark.
(b) Alloy grade.
(c) Rivet size.

2.8 Certification

2.8.1 The test certificate for each consignment of manufactured rivets is to include the following particulars:
(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Specification.

■ *Section 3* **Aluminium alloy castings**

3.1 Scope

3.1.1 Provision is made in this Section for aluminium alloy castings intended for use in the construction of ships, ships for liquid chemicals and other marine structures and liquefied gas piping systems where the design temperature is not lower than minus 165°C. These materials should not be used for piping systems outside cargo tanks except for short lengths of pipes attached to the cargo tanks in which case fire-resisting insulation should be provided.

3.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2 and also with the requirements of this Section.

3.1.3 As an alternative to 3.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

3.2 Manufacture

3.2.1 Castings are to be manufactured at foundries approved by LR.

3.3 Quality of castings

3.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

3.4 Chemical composition

3.4.1 The chemical composition of a sample from each cast is to comply with the requirements given in Table 8.3.1. Suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

3.4.2 Where it is proposed to use alloys not specified in Table 8.3.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.4.3 When a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor.

Table 8.3.1 Chemical composition, percentage

Alloy / Element	Al–Mg 3	Al–Si 12	Al–Si 10 Mg	Al–Si 7 High purity
Copper	0,1 max.	0,1 max.	0,1 max.	0,1 max.
Magnesium	2,5—4,5	0,1 max.	0,15—0,4	0,25—0,45
Silicon	0,5 max.	11,0—13,5	9,0—11,0	6,5—7,5
Iron	0,5 max.	0,7 max.	0,6 max.	0,2 max.
Manganese	0,6 max.	0,5 max.	0,6 max.	0,1 max.
Zinc	0,2 max.	0,1 max.	0,1 max.	0,1 max.
Chromium	0,1 max.	—	—	—
Titanium	0,2 max.	0,2 max.	0,2 max.	0,2 max.
Others each	0,05 max.	0,05 max.	0,05 max.	0,05 max.
Total	0,15 max.	0,15 max.	0,15 max.	0,15 max.
Aluminium	Remainder	Remainder	Remainder	Remainder

3.5 Heat treatment

3.5.1 Castings are to be supplied in the following conditions:

Grade Al-Mg 3 – as-manufactured
Grade Al-Si 12 – as-manufactured
Grade Al-Si 10 Mg – as-manufactured or solution heat treated and precipitation hardened
Grade Al-Si 7 Mg (high purity) – solution heat treated and precipitation hardened.

3.6 Mechanical tests

3.6.1 At least one tensile specimen is to be tested from each cast and, where heat treatment is involved, for each heat treatment batch from each cast. Where continuous melting is employed, 500 kg of fettled castings may be regarded as a cast.

3.6.2 The test samples are to be separately cast in moulds made from the same type of material as used for the castings. These moulds should conform to National Standards.

3.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be maintained during the preparation of test specimens.

3.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent prior to testing.

3.6.5 The results of all tensile tests are to comply with the appropriate requirements given in Table 8.3.2 and/or Table 8.3.3.

Table 8.3.2 Minimum mechanical properties for acceptance purposes of sand-cast and investment cast reference test pieces

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	150	3
Al–Si 10 Mg	M	150	2
Al–Si 10 Mg	TF	220	1
Al–Si 7 Mg	TF	230	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

Table 8.3.3 Minimum mechanical properties for acceptance purposes of chill-cast reference test piece

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	170	3
Al–Si 10 Mg	M	170	3
Al–Si 10 Mg	TF	240	1,5
Al–Si 7 Mg	TF	250	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

3.6.6 Where the results of a test do not comply with the requirements, the re-test procedure detailed in Ch 2,1.4 is to be applied. Where castings are to be used in the heat treated condition, the re-test sample must have been heat treated together with the castings it represents.

3.7 Visual examination

3.7.1 All castings are to be cleaned and adequately prepared for inspection.

3.7.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

3.7.3 Before acceptance, all castings are to be presented to the Surveyor for visual examination.

3.8 Rectification of defective castings

3.8.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

3.8.2 Where appropriate, repair by welding may be accepted at the discretion of the Surveyor. Such repair is to be made in accordance with an approved procedure.

3.9 Pressure testing

3.9.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence and to the satisfaction of the Surveyor.

3.10 Identification

3.10.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the casting when required.

3.10.2 All castings which have been tested and inspected with satisfactory results are to be clearly marked with the following details:

(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of the Surveyor responsible for the inspection.
(d) Test pressure where applicable.
(e) Date of final inspection.

3.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

3.11 Certification

3.11.1 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which have been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and alloy type.
(c) Identification number.
(d) Ingot or cast analysis.
(e) General details of heat treatment, where applicable.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

■ *Section 4*
Aluminium/steel transition joints

4.1 Scope

4.1.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating.

4.1.2 Each individual application is to be separately approved as required by the relevant Rules dealing with design and construction.

4.2 Manufacture

4.2.1 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.2.2 The aluminium material is to comply with the requirements of Section 1 and the steel is to be of an appropriate grade complying with the requirements of Ch 3,2.

4.2.3 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give reasonable equivalence to the requirements of 4.2.2 or are approved for a specific application.

4.2.4 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.3 Visual and non-destructive examination

4.3.1 Each composite plate is to be subjected to 100 per cent visual and ultrasonic examination in accordance with a relevant National Standard to determine the extent of any unbonded areas. Unbonded areas are unacceptable and any such area plus 25 mm of surrounding sound material is to be discarded.

4.4 Mechanical tests

4.4.1 Two shear test specimens and two tensile test specimens are to be taken from each end of each composite plate for tests to be made on the bond strength. One shear and one tensile test specimen from each end are to be tested at ambient temperature after heating to the maximum allowable interface temperature, *see* 4.2.1; the other two specimens are to be tested without heat treatment.

4.4.2 Shear tests may be made on a specimen as shown in Fig. 8.4.1 or an appropriate equivalent. Tensile tests may be made across the interface by welding extension pieces to each surface or by the ram method shown in Fig. 8.4.2 or by an appropriate alternative method.

4.4.3 The shear and tensile strengths of all the test specimens are to comply with the requirements of the manufacturing specification.

4.4.4 If either the shear or tensile strength of the bond is less than the specified minimum but not less than 70 per cent of the specified minimum, two additional shear and two tensile test specimens from each end of the composite plate are to be tested and, in addition, bend tests as described in 4.4.6 and Table 8.4.1 are to be made.

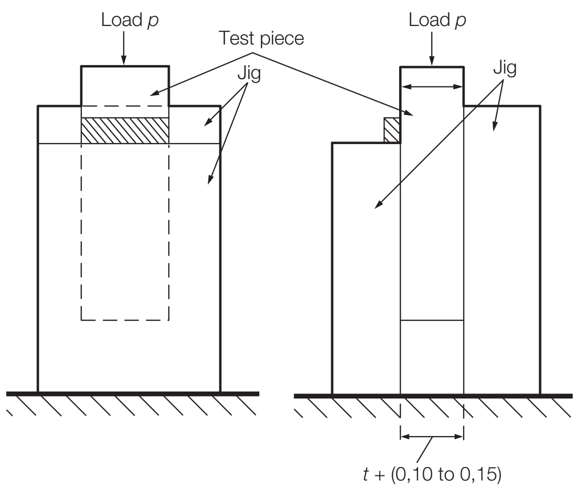


Fig. 8.4.1
Specimen and procedure for shear tests

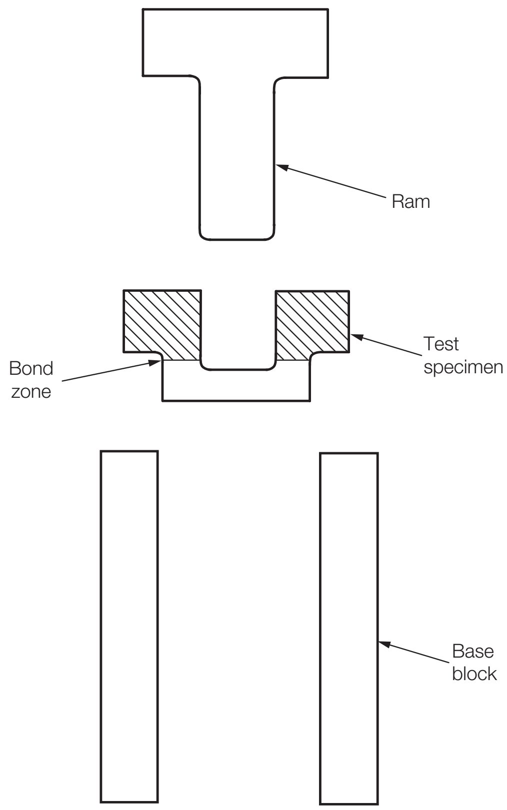


Fig. 8.4.2 Ram tensile test

4.4.5 If either the shear or tensile strength of the bond is less than 70 per cent of the specified minimum the cause is to be investigated. After evaluation of the results of this investigation, LR will consider the extent of composite plate which is to be rejected.

Table 8.4.1 Bend tests on explosion bonded aluminium/steel composites

Type of test	Minimum bend, degrees	Diameter of former
Aluminium in tension	90	3*T*
Steel in tension	90	3*T*
Side bend	90	6*T*
NOTE *T* is the total thickness of the composite plate.		

4.4.6 Bend tests, when required, are to be made under the following conditions, as listed in Table 8.4.1:
(a) The aluminium plate is in tension.
(b) The steel plate is in tension.
(c) A side bend is applied.

4.5 Identification

4.5.1 Each acceptable transition strip is to be clearly marked with the following particulars:
(a) LR or Lloyd's Register and the abbreviated name of LR's local office.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the grade of aluminium.
(d) Identification mark for the grade of steel.
The particulars are to be stamped on the aluminium surface at one end of the strip.

4.6 Certification

4.6.1 Each test certificate or shipping statement is to include the following particulars:
(a) Purchaser's name and order number.
(b) The contract number for which the material is intended, if known.
(c) Address to which the material is dispatched.
(d) Description and dimensions of the material.
(e) Specifications or grades of both the aluminium alloy and the steel and any intermediate layer.
(f) Cast numbers of the steel and aluminium plates.
(g) Identification number of the composite plate.
(h) Mechanical test results (not required on shipping statement).

Section

■ *Section 1* Castings for propellers

1.1 Scope

1.1.1 This Section gives the requirements for copper alloy castings for one-piece propellers and separately cast blades and bosses for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers and propulsors fitted to podded drives and azimuth units.

1.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and the specific requirements of this Section.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application.

1.1.4 The appropriate requirements of this Section may also be applied to the repair and inspection of propellers which have been damaged during service.

1.1.5 Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 All castings are to be manufactured at foundries approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The pouring is to be carried out into dried moulds using degassed liquid metal. The pouring is to avoid turbulent flow. Special devices and/or procedures are to be used to prevent slag flowing into the mould.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.3.2 The removal and repair of defects are dealt with in 1.9 and 1.10.

1.4 Chemical composition

1.4.1 The chemical compositions of samples from each melt are to comply with the manufacturing specification approved by LR and also with the overall limits given in Table 9.1.1. In addition to carrying out chemical analysis for the elements given in the Table, it is expected that manufacturers will ensure that any harmful residual elements are within acceptable limits.

1.4.2 The use of alloys whose chemical compositions are different from those detailed in Table 9.1.1 will be given special consideration by LR.

1.4.3 The manufacturer is to maintain records of all chemical analyses, which are to be made available to the Surveyor so that he can satisfy himself that the chemical composition of each casting is within the specified limits.

1.4.4 When a melt is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor. If any foundry returns are added to the melts, the ingot manufacturer's chemical analyses are to be supplemented by frequent checks as required by the Surveyor.

Table 9.1.1 Chemical composition of propeller and propeller blade castings

Alloy designation	Chemical composition of ladle samples %							
	Cu	Sn	Zn	Pb	Ni	Fe	Al	Mn
Grade Cu 1 Manganese bronze (high tensile brass)	52–62	0,1–1,5	35–40	0,5 max.	1,0 max.	0,5–2,5	0,5–3,0	0,5–4,0
Grade Cu 2 Ni-manganese bronze (high tensile brass)	50–57	0,1–1,5	33–38	0,5 max.	2,5–8,0	0,5–2,5	0,5–2,0	1,0–4,0
Grade Cu 3 Ni-aluminium bronze	77–82	0,1 max.	1,0 max.	0,03 max.	3,0–6,0	2,0–6,0	7,0–11,0	0,5–4,0
Grade Cu 4 Mn–aluminium bronze	70–80	1,0 max.	6,0 max.	0,05 max.	1,5–3,0	2,0–5,0	6,5–9,0	8,0–20,0

1.4.5 For alloys Grade Cu 1 and Cu 2, the zinc equivalent shall not exceed 45 per cent, and is to be calculated using the following formula:

$$\text{zinc equivalent \%} = 100 - \frac{100 \times \%Cu}{100 + A}$$

where A is the algebraic sum of the following:

1 x % Sn
5 x % Al
–0,5 x % Mn
–0,1 x % Fe
–2,3 x % Ni

1.4.6 Samples for metallographic examination are to be prepared from the ends of test bars cast from every melt of Grade Cu 1 and Cu 2 alloys. The proportion of alpha-phase determined from the average of at least five counts is to be not less than 25 per cent.

1.5 Heat treatment

1.5.1 At the option of the manufacturer, castings may be supplied in the ‘as-cast’ or heat treated condition. However, if heat treatment is to be applied, full details are to be included in the manufacturing specification.

1.5.2 If any welds are made in the propeller casting, stress relief heat treatment is required in order to minimize the residual stresses. Requirements concerning such heat treatment are given in 1.10.

1.6 Test material

1.6.1 Test samples are to be cast separately from each melt used for the manufacture of propeller or propeller blade castings.

1.6.2 The test samples are to be of the keel block type, generally in accordance with the dimensions given in Fig. 9.1.1 and are to be cast in moulds made from the same type of material as used for the castings.

1.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be transferred and maintained during the preparation of test specimens.

1.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

1.7 Mechanical tests

1.7.1 At least one tensile test specimen representative of each cast is to be prepared. The dimensions of this test specimen are to be in accordance with Fig. 2.2.1 in Chapter 2.

1.7.2 The results of all tensile tests are to comply with the requirements given in Table 9.1.2.

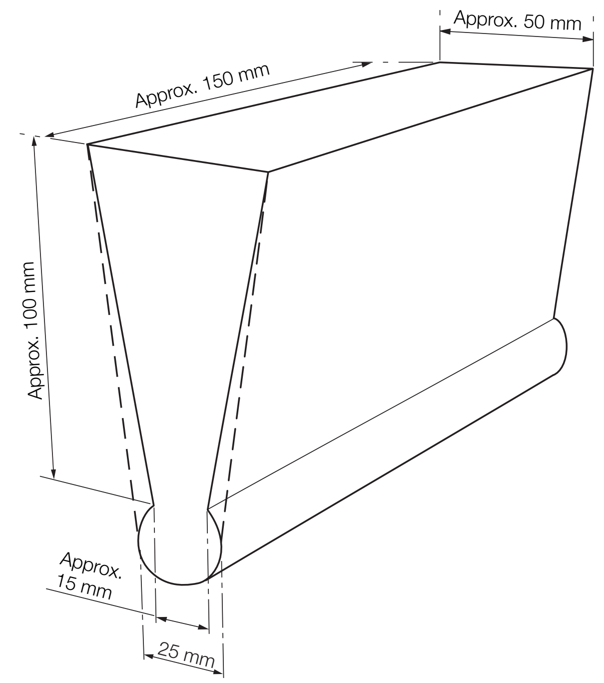


Fig. 9.1.1 Keel block type test sample

Table 9.1.2 Mechanical properties for acceptance purposes: propeller and propeller blade castings

Alloy designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum
Grade Cu 1 Manganese bronze (high tensile brass)	175	440	20
Grade Cu 2 Ni-manganese bronze (high tensile brass)	175	440	20
Grade Cu 3 Ni-aluminium bronze	245	590	16
Grade Cu 4 Mn-aluminium bronze	275	630	18

1.7.3 The mechanical properties of alloys whose chemical compositions do not accord with Table 9.1.1 are to comply with a manufacturing specification approved by LR.

1.8 Inspection and non-destructive examination

1.8.1 Propeller castings should be visually inspected at all stages of manufacture. The manufacturer is to draw any significant imperfections to the attention of the Surveyor. Such imperfections are to be verified in accordance with 1.9.

1.8.2 All finished castings are to be subjected to a comprehensive visual examination by the Surveyor, including internal surfaces such as the bore and bolt holes.

1.8.3 For the purpose of these requirements, the blades of propellers, including CPP blades, are divided into three severity Zones A, B and C as shown in Fig. 9.1.2 and detailed in 1.8.4 for blades having skew angles of 25° or less and 1.8.5 for blades having skew angles of greater than 25°.

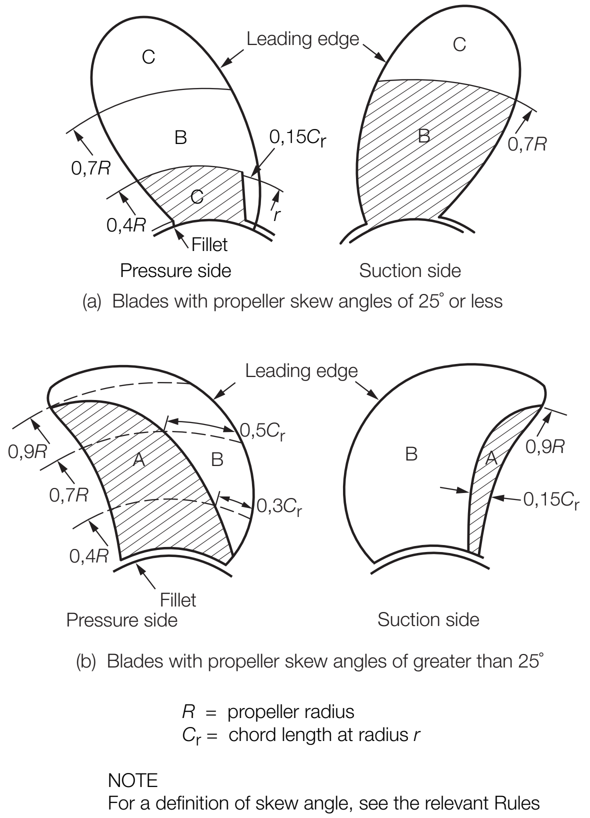


Fig. 9.1.2 Severity zones in all propeller blades

1.8.4 **Skew angles of 25° or less:**

- Zone A is the area on the pressure side of the blade from and including the root fillet to 0,4R and bounded by the trailing edge and by a line at a distance 0,15 times the chord length from the leading edge.
- Zone B includes the areas inside 0,7R on both sides of the blade, excluding Zone A.
- Zone C includes the areas outside 0,7R on both sides of the blade.

1.8.5 **Skew angles of greater than 25°**:

- Zone A is the area on the pressure side of the blade bounded by, and including, the root fillet and a line running from the junction of the leading edge with the root fillet to the trailing edge at 0,9R and passing through the mid-point of the chord at 0,7R and a point situated at 0,3 of the chord length from the leading edge at 0,4R.
- Zone A also includes the area along the trailing edge on the suction side of the blade from the root to 0,9R and with its inner boundary at 0,15 of the chord length tapering to meet the trailing edge at 0,9R.
- Zone B constitutes the whole of the remainder of the blade surfaces.

1.8.6 In propeller blades with continuously loaded tips (CLT), the whole of the tip plate and the adjoining blade to a distance of 100 mm is to be regarded as severity Zone B, *see* Fig. 9.1.3. For propellers with diameters less than 2 m, the width of this zone may be reduced to one tenth of the propeller radius.

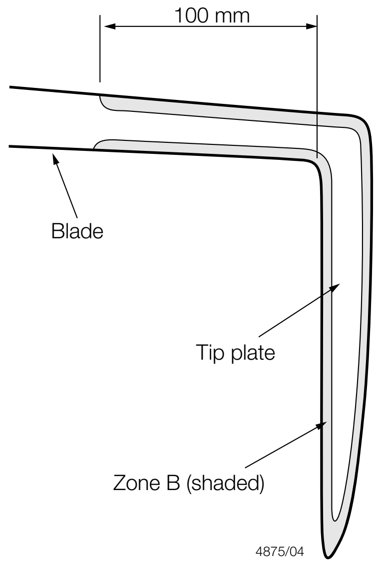


Fig. 9.1.3
Severity Zone B at Continuously loaded blade tip

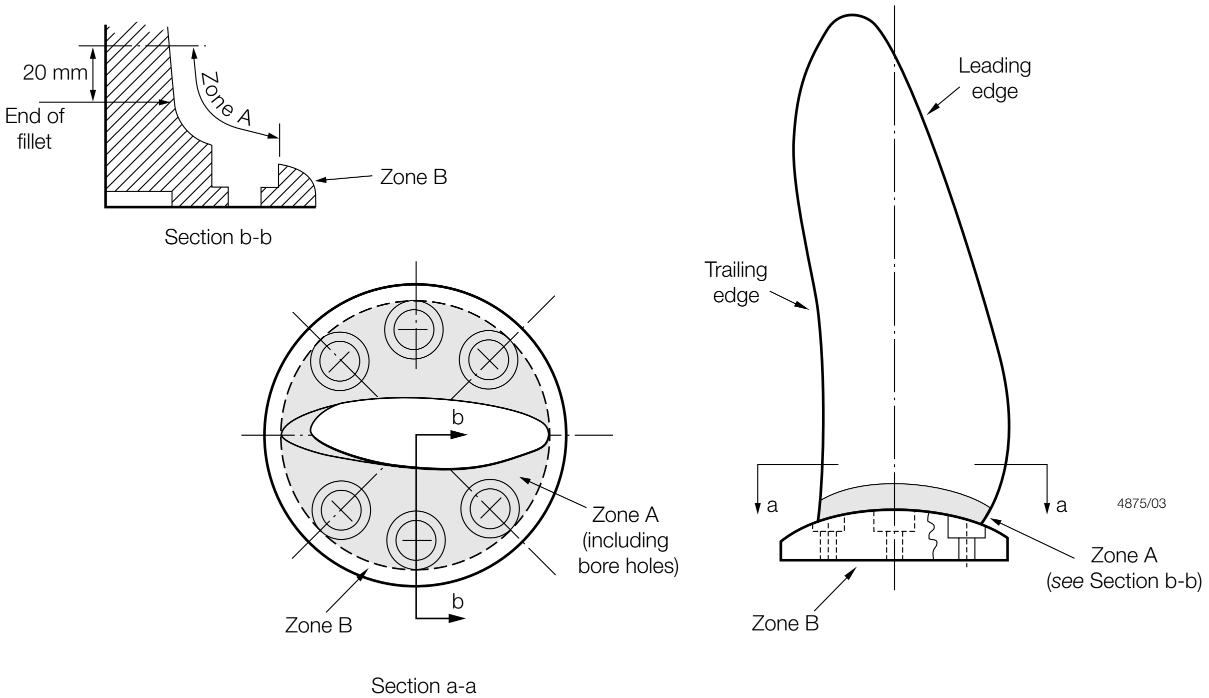
1.8.7 In addition, the palm of a CPP blade is divided into severity Zones A and B as shown in Fig. 9.1.4.

1.8.8 If a CPP blade has an integrally cast journal, the fillets of the journal and the adjoining material up to a distance of 20 mm from the fillet run-outs are to be regarded as Zone B, as indicated in Fig. 9.1.5. The remainder of the surface of the journal may be regarded as Zone C.

1.8.9 Hubs of controllable pitch propellers are to contain a Zone A region at each blade port as shown in Fig. 9.1.6. The remainder may be regarded as Zone C.

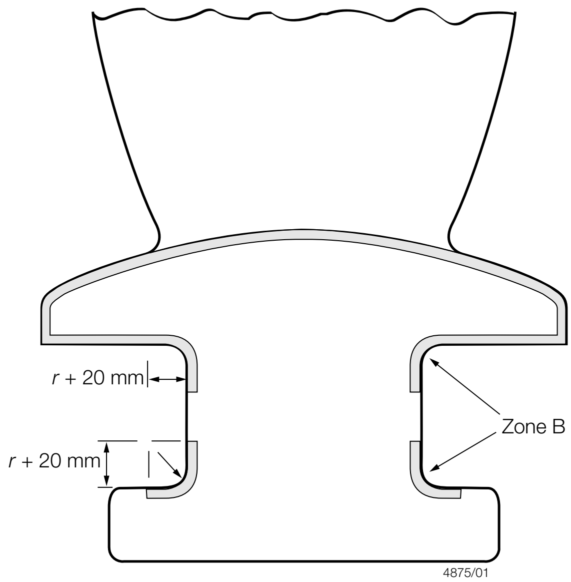
1.8.10 On completion of machining and grinding, the whole surface of each casting is to be subjected to a dye penetrant inspection in accordance with a standard or specification approved by LR.

1.8.11 All dye penetrant inspections on Zone A areas in the finished condition are to be made in the presence of the Surveyor.



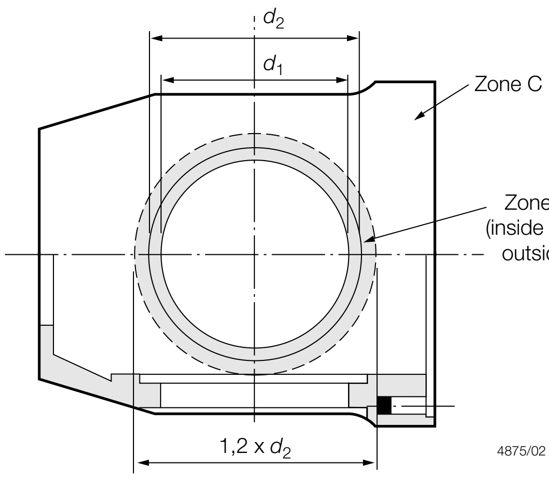
The surfaces of blades are to be divided into severity zones in accordance with Fig. 9.1.2

Fig. 9.1.4 Severity zones for controllable pitch propeller blades



The surfaces of the journal which are not shaded are to be regarded as severity Zone C

Fig. 9.1.5
Severity zones in integrally cast CPP blade journals



(d_1 and d_2 = diameters)

Fig. 9.1.6
Severity zones for controllable pitch propeller hub

1.8.12 Dye penetrant inspections on Zones B and C are to be performed by the manufacturer and may be witnessed by the Surveyor at his request.

1.8.13 The surface to be inspected shall be divided into reference areas of 100 cm^2. The indications detected shall, with respect to their size and number, not exceed the values given in Table 9.1.3. The area shall be taken in the most unfavourable location relative to the indication being evaluated.

1.8.14 Indications exceeding the acceptance standard in Table 9.1.3 shall be repaired in accordance with 1.9.

1.8.15 All defects requiring repair by welding in new propeller castings are to be recorded on sketches showing their locations and dimensions. Copies of these sketches are to be presented to the Surveyor prior to repair.

1.8.16 Where repairs have been made either by grinding or welding, the repaired areas are to be subjected to dye penetrant inspection in the presence of the Surveyor, regardless of their location.

1.8.17 Where no welds have to be made on a casting, the manufacturer is to provide the Surveyor with a statement that this is the case.

1.8.18 Where it is suspected that a casting contains internal defects, radiographic and/or ultrasonic examination may be required by the Surveyor. The acceptance criteria are to be agreed between the manufacturer and LR.

1.8.19 The measurement of dimensional accuracy is the responsibility of the manufacturer but the report on dimensional inspection is to be presented to the Surveyor who may require checks to be made and to witness such checks.

1.8.20 Static balancing is to be carried out on all propellers in accordance with the approved plan. Dynamic balancing is necessary for propellers running above 500 rpm.

1.9 Rectification of defective castings

1.9.1 The rectification of defective propeller and propeller blade castings is to be carried out in accordance with the requirements given in 1.9.2 to 1.9.12.

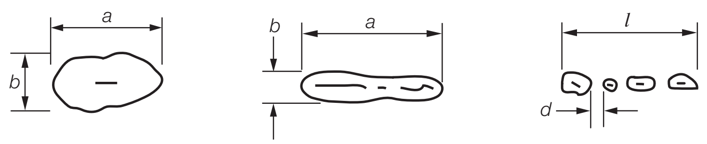
1.9.2 The rectification of small indications within the acceptance standard of Table 9.1.3 is not generally required except where they occur in closely spaced groups.

1.9.3 Where, in the surface of the end face or bore of a propeller boss, local pores are present which do not themselves adversely affect the strength of the casting, they may be filled with a suitable plastic filler after the appropriate preparation of the defective area. The foundry is to maintain records and details of all castings which have been so rectified.

Table 9.1.3 Allowable number and size of dye penetrant indications in a reference area of 100cm² (*see* Note 1)

Severity Zones	Max. total number of indications	Type of indications (*see* Note 2)	Max. number of each type (*see* Notes 3 and 4)	Max. acceptable value for ‘a’ or ‘l’ of indications (mm) (*see* Note 2)
A	7	Non-linear Linear Aligned	5 2 2	4 3 3
B	14	Non-linear Linear Aligned	10 4 4	6 6 6
C	20	Non-linear Linear Aligned	14 6 6	8 6 6

NOTES
1. The reference area is defined as an area of 0,1 m^2, which may be square or rectangular, with the major dimension not exceeding 250 mm. The area shall be taken in the most unfavourable location relative to the indication being evaluated.
2. Non-linear, linear and aligned indications are defined as follows:



$\frac{a}{b} < 3$ non-linear

$\frac{a}{b} \geq 3$ linear

$d \leq 2$ mm aligned

3. Only indications that have any dimension greater than 1,5 mm shall be considered relevant.
4. Single non-linear indications less than 2 mm in Zone A and less than 3 mm in other zones may be disregarded.
5. The total number of non-linear indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

1.9.4 Where unacceptable defects are found in a casting, they are to be removed by mechanical means, and the surfaces of the resulting depressions are subsequently to be ground smooth. Complete elimination of the defects is to be proved by adequate dye penetrant inspection.

1.9.5 Shallow grooves or depressions resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding.

1.9.6 Welded repairs are to be undertaken only when they are considered to be necessary and approved by the Surveyor. In general, welds having an area less than 5 cm^2 are to be avoided.

1.9.7 All weld repairs are to be carried out in accordance with qualified procedures by suitably qualified welders, and are to be completed to the satisfaction of the Surveyor. Records are to be made available to the Surveyor.

1.9.8 Welding is generally not permitted in Zone A and will only be allowed after special consideration.

1.9.9 Prior approval by the Surveyor is required for any welds in Zone B. Complete details of the repair procedure are to be submitted for each case.

1.9.10 Repair by welding is allowed in Zone C provided that there is compliance with 1.9.6 and 1.9.7.

1.9.11 The maximum area of any single repair and the maximum total area of repair in any one zone or region are given in Table 9.1.4.

1.9.12 Where it is proposed to exceed the areas given in Table 9.1.4, the nature and extent of the repair work are to be approved by the Surveyor before commencement of the repair.

1.10 Weld repair procedure

1.10.1 Welding is to be carried out under cover in positions free from draughts and adverse weather conditions.

1.10.2 The manufacturer is to submit a detailed welding procedure specification covering the weld preparation, welding parameters, filler metal, preheating, post-weld heat treatment and inspection procedures.

1.10.3 Before welding is started, Welding Procedure Qualification tests are to be carried out and witnessed by the Surveyor. Each welder is to be qualified to carry out the proposed welding using the same process, consumable and position which are to be used for the repair.

1.10.4 Defects to be repaired by welding are to be removed completely by mechanical means (e.g. grinding, chipping or milling). Removal of defects is to be demonstrated by dye penetrant inspection in the presence of the Surveyor. The excavation is to be prepared in a manner which will allow good fusion and is to be clean and dry.

Table 9.1.4 Permissible rectification of new propellers by welding

Severity zone or region	Maximum individual area of repair	Maximum total area of repairs
Zone A	Weld repairs not generally permitted	
Zone B	60 cm^2 or 0,6% x S whichever is the greater	200 cm^2 or 2% x S, whichever is the greater in combined Zones B and C but not more than 100 cm^2 or 0,8% x S, whichever is the greater, in Zone B on the pressure side
Zone C		
Other regions (*see* Note)	17 cm^2 or 1,5% area of the region whichever is the greater	50 cm^2 or 5% x area of the region whichever is the greater

where S = area of one side of a blade = $0,79 \dfrac{D^2 B}{N}$

D = finished diameter of propeller
B = developed area ratio
N = number of blades

NOTE
Other regions include:
(a) the bore;
(b) the forward and aft faces of the boss;
(c) the outer surface of the boss to the start of the blade root fillets;
(d) the inner face of a CPP blade palm;
(e) all surfaces of CPP nose cones;
(f) the surfaces of integral journals to CPP blades other than the fillets.

1.10.5 Metal arc welding with the electrodes or filler wire used in the procedure tests is to be used for all types of repairs. Welds should preferably be made in the downhand (flat) position. Where necessary, suitable preheat is to be applied before welding, and the preheat temperature is to be maintained until welding is completed.

1.10.6 When flux coated electrodes are used they are to be dried immediately before use, in accordance with the manufacturer's instructions.

1.10.7 All slag, undercuts and other defects are to be removed before the subsequent run is deposited.

1.10.8 With the exception given in 1.10.9, all weld repairs in areas of solid propellers exposed to sea-water, and all repairs to separately cast blades, are to be stress relief heat treated.

1.10.9 Stress relief heat treatment is not mandatory after welding Grade Cu 3 castings in Zone C unless a welding consumable susceptible to stress corrosion (e.g. complying with the composition range of Grade Cu 4) is used. All welds in Zones A and B however, must be stress relieved by heat treatment, regardless of alloy.

1.10.10 Propeller and propeller blades are to be stress relieved within the following temperature ranges:

alloy Grades Cu 1 and Cu 2	350°C to 550°C
alloy Grade Cu 3	450°C to 500°C
alloy Grade Cu 4	450°C to 600°C

Soaking times are to be in accordance with Table 9.1.5, and subsequent cooling from the soaking temperature is to be suitably controlled to minimize residual stresses and is not to exceed 50°C per hour until the temperature is below 200°C. Care should be taken to avoid heating castings in the Grade Cu 3 alloy at temperatures between 300° and 400°C for prolonged periods.

Table 9.1.5 Soaking times for stress relief heat treatment of copper alloy propellers

Stress relief temperature °C (*see* Notes)	Alloy Grade Cu1 and Cu2		Alloy Grade Cu3 and Cu4	
	Hours per 25 mm of thickness	Maximum recommended total time hours	Hours per 25 mm of thickness	Maximum recommended total time hours
350	5	15	—	—
400	1	5	—	—
450	1/2	2	5	15
500	1/4	1	1	5
550	1/4	1/2	1/2	2
600	—	—	1/4	1

NOTES
1. Treatment at 550°C is not applicable to alloy Grade Cu3.
2. Treatment at 600°C is only applicable to alloy Grade Cu4.

1.10.11 Stress relief heat treatment is to be carried out, where possible, in furnaces having suitable atmosphere and temperature control. Sufficient thermocouples are to be attached to the casting to measure the temperature at positions of extremes of thickness.

1.10.12 As an alternative to 1.10.11, local stress relief heat treatment may be accepted, provided that the Surveyor is satisfied that the technique will be effective and that adequate precautions are taken to prevent the introduction of detrimental temperature gradients. Where local stress relief heat treatment is approved, adequate temperature control is to be provided. The area of the propeller or blade adjacent to the repair is to be suitably monitored and insulated to ensure that the required temperature is maintained and that temperature gradients are moderate. Care should be taken to select the shape of an area to be heat treated which will minimize residual stresses.

1.10.13 On completion, welds are to be ground smooth for visual examination and dye penetrant inspection. Where a propeller or propeller blade is to be stress relief heat treated, a visual examination is to be made before heat treatment, and both visual and dye penetrant examinations are to be made after the stress relief heat treatment. Irrespective of location, all weld repairs are to be assessed according to Zone A in Table 9.1.3.

1.10.14 The foundry is to maintain full records detailing the weld procedure, heat treatment and extent and location on drawings of repairs made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.10.15 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

1.11 Identification

1.11.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:
(a) Identification mark which will enable the full history of the item to be traced.
(b) Alloy grade.
(c) LR or Lloyd's Register and the abbreviated name of LR's local office.
(d) Personal stamp of Surveyor responsible for the final inspection.
(e) Date of final inspection.
(f) Skew angle, if in excess of 25°. *See* the relevant Rules for the definition of skew angle.

1.12 Certification

1.12.1 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting:
(a) Purchaser's name and order number.
(b) Description of casting.
(c) Alloy designation and/or trade name.
(d) Identification number of casting.
(e) Cast identification number if different from (d).
(f) Details of heat treatment, where applicable.
(g) Skew angle, if in excess of 25°. *See* the relevant Rules for the definition of skew angle.
(h) Final weight of casting.
(j) Results of non-destructive tests and details of test procedures.
(k) Proportion of alpha-structure for Cu1 and Cu2 alloys.
(l) Results of mechanical tests.
(m) A sketch showing the location and extent of welding repairs (if any).

■ *Section 2*
Castings for valves, liners and bushes

2.1 Scope

2.1.1 This Section makes provision for copper alloy castings for valves, liners, bushes and other fittings intended for use in the construction of ships, other marine structures, machinery and pressure piping systems.

2.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2, and also with the requirements given in this Section.

2.1.3 As an alternative to 2.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

2.2 Manufacture

2.2.1 Castings are to be manufactured at foundries approved by LR.

2.3 Quality of castings

2.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

2.4 Chemical composition

2.4.1 The chemical composition is to comply with the requirements of a National or International Standard and, where appropriate, with the limits for the principal elements of the preferred alloys listed in Tables 9.2.1 and 9.2.2.

2.4.2 With the exception given in 2.4.3, chemical analysis is required on each cast.

2.4.3 Where a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional check tests as requested by the Surveyor. The frequency of these check tests should, as a minimum, be one in every ten casts. If one of these check analyses fails to comply with the specification, checks are to be made on the previous and subsequent melts. If one or both of these further analyses is unsatisfactory, chemical analysis is to be carried out on all further melts until the Surveyor is satisfied that a return can be made to the use of occasional check tests.

Table 9.2.1 Chemical compositions of long freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition						Typical applications
		Cu	Sn	Zn	Pb	Ni	P	
Phosphor bronze	Cu Sn11P Cu Sn12	87,0 – 89,5 85,0 – 88,5	10,0 – 11,5 11,0 – 13,0	0,05 max. 0,50 max.	0,25 max. 0,7 max.	0,10 max. 2,0 max.	0,5 – 1,0 0,60 max.	Liners, bushes, valves and fittings
Gunmetal	Cu Sn10 Zn2	Remainder	9,5 – 10,5	1,75 – 2,75	1,5 max.	1,0 max.	—	Liners, valves and fittings
Leaded gunmetal	Cu Sn5 Zn5 Pb5 Cu Sn7 Zn2 Pb3 Cu Sn7 Zn4 Pb7 Cu Sn6 Zn4 Pb2	83,0 – 87,0 85,0 – 89,0 81,0 – 85,0 86,0 – 90,0	4,0 – 6,0 6,0 – 8,0 6,0 – 8,0 5,5 – 6,5	4,0 – 6,0 1,5 – 3,0 2,0 – 5,0 3,0 – 5,0	4,0 – 6,0 2,5 – 3,5 5,0 – 8,0 1,0 – 2,0	2,0 max. 2,0 max. 2,0 max. 1,0 max.	0,10 max. 0,10 max. 0,10 max. 0,05 max.	Bushes, valves and fittings
Leaded bronze	Cu Sn10 Pb10 Cu Sn5 Pb9 Cu Sn7 Pb15 Cu Sn5 Pb20	78,0 – 82,0 80,0 – 87,0 74,0 – 80,0 70,0 – 78,0	9,0 – 11,0 4,0 – 6,0 6,0 – 8,0 4,0– 6,0	2,0 max. 2,0 max. 2,0 max. 2,0 max.	8,0 – 11,0 8,0 – 10,0 13,0 – 17,0 18,0 – 23,0	2,0 max. 2,0 max. 0,5 – 2,0 0,5 – 2,5	0,10 max. 0,10 max. 0,10 max. 0,10 max.	Bushes

Table 9.2.2 Chemical compositions of short freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition								Typical applications
		Cu	Ni	Fe	Mn	Cr	Nb	Si	Al	
Copper 30% nickel	Cu Ni30 Fe1 Mn1 Cu Ni30 Fe1 Mn1 Nb Si Cu Ni30 Cr2 Fe Mn Si (*see* Note)	64,5 min. Remainder Remainder	29,0–31,0 29,0–31,0 29,0–32,0	0,5–1,5 0,5–1,5 0,5–1,0	0,6–1,2 0,6–1,2 0,5–1,0	– – 1,5–2,0	– 0,5–1,0 –	0,1 max. 0,3–0,7 0,15–0,50	– – –	Flanges, valves and fittings
Copper 10% nickel	Cu Ni10 Fe1 Mn1	84,5 min.	9,0–11,0	1,0–1,8	1,0–1,5	–	1,0 max.	0,10 max.	–	Flanges, valves and fittings
Aluminium bronze	Cu Al10 Fe5 Ni5 Cu Al11 Fe6 Ni6	76,0–83,0 72,0–78,0	4,0–6,0 4,0–7,5	4,0–5,5 4,0–7,0	3,0 max. 2,5 max.	– –	– –	0,1 max. 0,1 max.	8,5–10,5 10,0–12,0	Bushes, valves and fittings

NOTE
Normally alloy Cu Ni30 Cr2 Fe Mn Si contains 0,1 to 0,25% titanium and 0,05 to 0,15% zirconium.

2.5 Heat treatment

2.5.1 Where required by the specification, castings may be supplied in either the ‘as-cast’ or heat treated condition.

2.5.2 Where castings are supplied in a heat treated condition, the test samples are to be heat treated with the castings they represent prior to the preparation of the tensile test specimens.

2.6 Test material

2.6.1 Test material sufficient for the tests specified in 2.6.4 and for possible re-test purposes is to be provided for each cast of material.

2.6.2 The test material is to be separately cast into moulds made of the same material as that used for the castings they represent.

2.6.3 For the alloys listed in Table 9.2.1, sand cast test bars are generally to be in accordance with Fig. 9.2.1.

2.6.4 For the alloys listed in Table 9.2.2, keel block type test samples are to be in accordance with Fig. 9.1.1.

2.6.5 If it is proposed to use any other form of test bar, this is to be agreed in advance with the Surveyor.

2.6.6 As an alternative, for liners and bushes, the test material may be taken from the ends of the castings.

2.7 Mechanical tests

2.7.1 A tensile test specimen is to be prepared from each test sample. The dimensions of the specimens are to comply with Fig. 2.2.1 or Fig. 2.2.2 in Chapter 2.

2.7.2 The results of all tests are to comply with the appropriate requirements given in Tables 9.2.3 and 9.2.4.

2.8 Inspection

2.8.1 All castings are to be cleaned and adequately prepared for inspection. Before acceptance, all castings are to be presented to the Surveyor for visual examination. This is to include the examination of internal surfaces, where applicable.

2.8.2 For valves and other pressure components, dye penetrant inspection is required and the Surveyor is to witness the tests.

2.8.3 The accuracy and verification of dimensions are the responsibility of the manufacturer. However, the report on dimensional inspection is to be presented to the Surveyor who may require checks to be made in his presence.

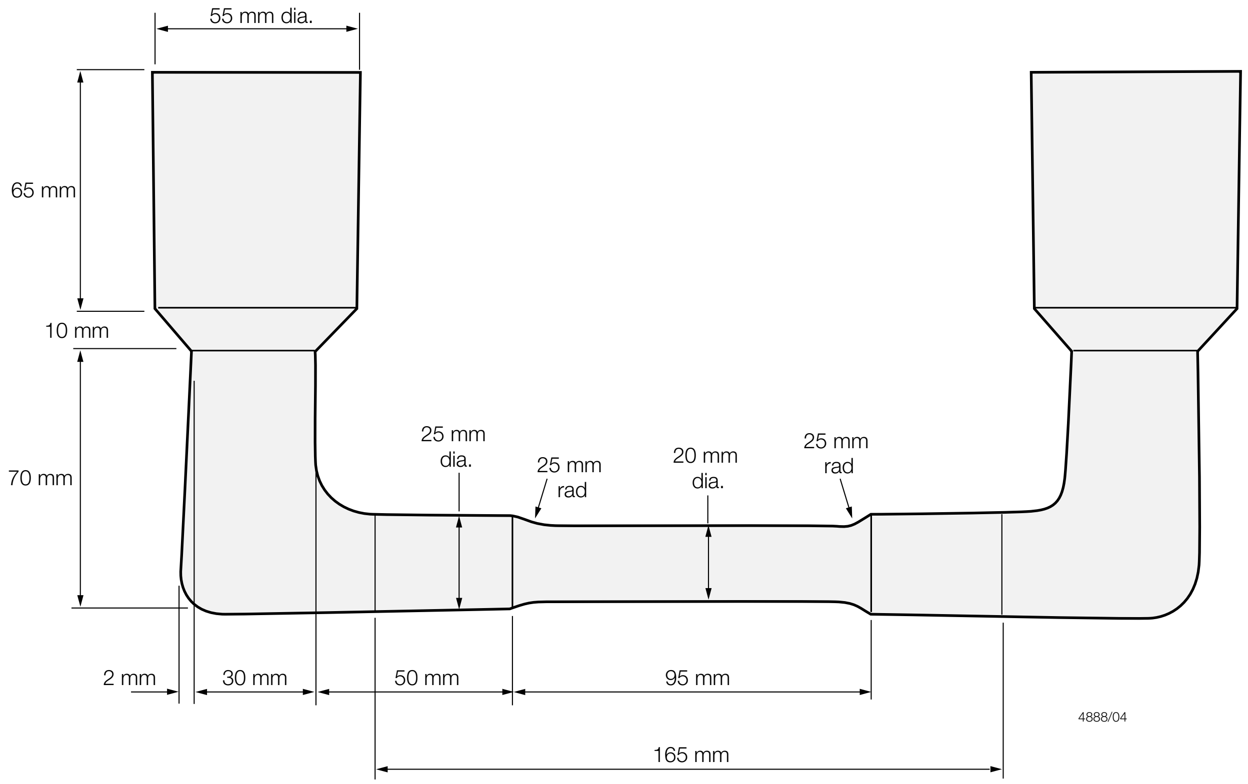


Fig. 9.2.1 Sand cast test bars for long freezing range alloys

Table 9.2.3 Mechanical properties of long freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm^2 minimum (*See* Note 1)		Tensile strength N/mm^2 minimum		Elongation on 5,65 $\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Phosphor bronze	Cu Sn11 P Cu Sn12	130 140	170 150	250 260	330 280	5 7	4 5
Gunmetal	Cu Sn10 Zn2	130	130	270	250	13	5
Leaded gunmetal	Cu Sn5 Zn5 Pb5 Cu Sn7 Zn2 Pb3 Cu Sn7 Zn4 Pb7 Cu Sn6 Zn4 Pb2	90 130 120 110	110 130 120 110	200 230 230 220	250 260 260 240	13 14 15 15	13 12 12 12
Leaded bronze	Cu Sn10 Pb10 Cu Sn5 Pb9 Cu Sn7 Pb15 Cu Sn5 Pb20	80 60 80 70	110 90 90 80	180 160 170 150	220 200 200 170	8 7 8 5	6 6 7 6

NOTES
1. The 0,2% proof stress values are given for information purposes only and, unless otherwise agreed, are not required to be verified by test.
2. Castings may be supplied in the chill cast condition in which case the mechanical properties requirements are to be in accordance with a specification agreed by LR.

Table 9.2.4 Mechanical properties of short freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm^2 minimum (*See* Note 1)		Tensile strength N/mm^2 minimum		Elongation on 5,65 $\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Copper 30% Nickel	Cu Ni30 Fe1 Mn1 Cu Ni30 Fe1 Mn1 Nb Si Cu Ni30 Cr2 Fe Mn Si	120 230 250	120 — —	340 440 440	340 — —	18 18 18	18 — —
Copper 10% Nickel	Cu Ni10 Fe1 Mn1	120	100	280	280	20	25
Aluminium Bronze	Cu Al10 Fe5 Ni5 Cu Al11 Fe6 Ni6	250 320	280 380	600 680	650 750	13 5	13 5

2.9 Rectification of defective castings

2.9.1 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

2.9.2 Proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to be satisfied that the number, position and size of the defects are such that the castings can be efficiently repaired.

2.9.3 Where approval is given for the repair by welding, complete elimination of the defects is to be proven by adequate non-destructive testing.

2.9.4 All welding is to be in accordance with an approved and qualified weld procedure and carried out by a qualified welder.

2.9.5 A statement and/or sketch detailing the extent and position of all weld repairs is to be prepared by the manufacturer as a permanent record. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

2.9.6 The alloys listed in Table 9.2.1 are not satisfactory for repair by welding which is generally not permitted. Weld repairs may, however, be considered in special circumstances provided that a suitable procedure, with proof of previous satisfactory repairs is submitted to the Surveyor.

2.9.7 The welding during manufacture of liners is not permitted in any alloy containing more than 0,5 per cent lead.

2.10 Pressure testing

2.10.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

2.11 Identification

2.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the casting when required.

2.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:
(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of the Surveyor responsible for inspection.
(d) Test pressure, where applicable.
(e) Date of final inspection.

2.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

2.12 Certification

2.12.1 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:
(a) Purchaser's name and order number.
(b) Description of castings and alloy grade.
(c) Identification number.
(d) Ingot or cast analysis.
(e) Full details of heat treatment, where applicable.
(f) Mechanical test results.
(g) Test pressure, where applicable.

2.12.2 In addition to 2.12.1, the manufacturer is to provide, where applicable, a statement and/or sketch detailing the extent and position of all weld repairs made to each casting.

■ *Section 3* Tubes

3.1 Scope

3.1.1 Provision is made in this Section for seamless copper and copper alloy tubes intended for use in condensers, heat exchangers and pressure piping systems.

3.1.2 Tubes for Class I and II pressure systems (as defined in the relevant Rules) are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2 and the requirements of this Section.

3.1.3 As an alternative to 3.1.2, tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

3.1.4 Tubes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of a National or International Standard recognized by LR. The manufacturer's test certificate will be acceptable and is to be provided for each batch of material.

3.2 Manufacture

3.2.1 Tubes for Class I and II pressure systems are to be manufactured at a works approved by LR for the grade of material being supplied.

3.2.2 Tubes for Class III pressure systems are not required to be manufactured at a works approved by LR.

3.3 Quality

3.3.1 Tubes are to be clean and free from surface and internal defects and residues from manufacturing operations.

3.3.2 The tubes are to be supplied in smooth, round, straight lengths, free from deleterious films in the bore. The ends are to be cut clean and square with the axis of the tube and are to be de-burred.

3.4 Dimensional tolerances

3.4.1 The tolerances on the wall thickness and diameter of the tubes are to be in accordance with a National or International Standard recognized by LR.

3.4.2 The measurement of dimensional accuracy and compliance with the specification are the responsibility of the manufacturer, but the reports are to be made available to the LR Surveyors, who may require checks to be made in their presence.

3.5 Chemical composition

3.5.1 The chemical composition is to comply with the requirements of a National or International Standard recognized by LR and comply with the base limits for the principal elements given in Table 9.3.1.

3.6 Heat treatment

3.6.1 Copper-phosphorus and aluminium brass tubes are to be supplied in the annealed condition. Aluminium brass tubes may additionally be required to be given a suitable stress relieving heat treatment when subjected to a cold straightening operation after annealing.

Table 9.3.1 Chemical composition of principal elements only

Designation	Chemical composition %								
	Cu	As	P	Fe	Pb	Ni	Al	Mn	Zn
Copper-phosphorus deoxidised–non-arsenical	99,85 min.	–	0,013–0,050	—	—	—	—	—	—
Copper-phosphorus deoxidised–arsenical	99,2 min.	0,30–0,50	0,013–0,050		—	—	—	—	—
Aluminium brass	76,0–79,0	0,02–0,06	—	0,06 max.	0,07 max.	—	1,8–2,5	—	Remainder
90/10 Copper-nickel-iron (*see* Note)	Remainder	—	—	1,0-2,0	—	9,0–11,0	—	0,5–1,0	—
70/30 Copper-nickel-iron (*see* Note)	Remainder	—	—	0,40–1,00	—	29,0–33,0	—	0,5–1,5	—

NOTE
Where the purchaser specifies that the product is intended for subsequent welding applications, the following limits will apply:

Zn	0,50% max.	S	0,02% max.
Pb	0,02% max.	C	0,05% max.
P	0,02% max.		

Table 9.3.2 Mechanical properties for acceptance purposes

Designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Drift expansion test % minimum	Grain size mm maximum (*see* Note)
Copper-phosphorus deoxidised–non-arsenical	65	220	40	40	—
Copper-phosphorus deoxidised–arsenical	65	220	40	40	—
Aluminium brass	125	320	40	30	0,045
90/10 Copper-nickel-iron	100	270	30	30	0,045
70/30 Copper-nickel-iron	120	360	30	30	0,045

NOTE
When a maximum grain size is specified, the structure is to be completely re-crystallized. The manufacturer is to guarantee the grain size, but testing of each batch will not be required.

3.6.2 Tubes in the copper-nickel iron alloys are to be supplied in a solution heat treated condition to ensure that no iron rich phases are present.

3.7 Mechanical tests

3.7.1 Tubes are to be presented for test in batches of 300 lengths. A batch is to consist of tubes of the same size, manufactured from the same material grade.

3.7.2 At least one length is to be selected at random from each batch and subjected to the following tests:
(a) Tensile test.
(b) Flattening test.
(c) Drift expanding test.

3.7.3 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

3.7.4 The flattening test is to be continued until the interior surfaces of the tube meet.

3.7.5 For the drift expanding test, the mandrel is to have an included angle of 45°.

3.7.6 The results of all mechanical tests are to comply with the appropriate requirements given in Table 9.3.2.

3.7.7 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

3.8 Visual examination

3.8.1 All tubes are to be visually examined. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the tubes to be carried out.

3.8.2 The inner and outer surfaces are to be clean and smooth but may have a superficial, dull iridescent film on both the inner and outer surfaces.

3.9 Stress corrosion cracking test

3.9.1 This is an accelerated test for detecting the presence in tubes of internal stresses which might result in failure, in storage or in service, due to stress corrosion cracking.

3.9.2 The test is applicable only to aluminium brass and copper-nickel-iron tubes.

3.9.3 The test specimen is to consist of a 150 mm length cut from the tube selected for mechanical tests in accordance with 3.7.2.

3.9.4 The test is to be carried out in accordance with a National or International Standard recognized by LR.

3.9.5 The test specimen is to be immersed in a mercurous nitrate solution at room temperature for 30 minutes. Aluminium brass specimens are to be examined for cracks immediately after rinsing, while copper-nickel-iron specimens are to be examined 24 hours after rinsing.

3.9.6 Should any specimen fail to meet the requirements of this test, then all tubes represented by that specimen are to be withdrawn. The tubes may be re-submitted after stress relieving treatments for full testing in accordance with 3.7 and 3.9.

3.10 Hydraulic test

3.10.1 Each tube is to be subjected to a hydraulic test at the manufacturer's works.

3.10.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 70 bar:

$$P = \frac{20st}{D}$$

where

P = test pressure, in bar
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
s = 40 for copper-phosphorus
60 for Al-brass and
90/10 copper nickel iron
75 for 70/30 copper nickel iron.

3.10.3 The test pressure is to be maintained for sufficient time to permit proof that the tubes do not weep, leak or undergo a permanent increase in diameter. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted.

3.10.4 Where it is proposed to adopt a test pressure other than that determined in 3.10.2, the proposal will be subject to special consideration.

3.10.5 Subject to special approval, an eddy current test can be accepted in lieu of the hydraulic test.

3.11 Rectification of defects

3.11.1 The repair of defects by welding is not permitted.

3.12 Identification

3.12.1 Tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Grade of material or designation code.
(d) Identification number and/or initials which will enable the full history of the item to be traced.

3.12.2 Identification is to be by rubber stamp or stencils. Hard stamping is not permitted.

3.13 Certification

3.13.1 The manufacturer is to provide the Surveyor with copies of the test certificate or shipping statement for all material which has been accepted.

3.13.2 Each test certificate is to contain the following particulars:

(a) Purchaser's name and order number.
(b) Specification or grade of material.
(c) Description and dimensions.
(d) Cast number and chemical composition.
(e) Mechanical test results.
(f) Results of stress corrosion cracking test, where applicable.
(g) Hydraulic test report.

■ *Section 1* Anchors

1.1 Scope

1.1.1 This Section makes provision for the manufacture and testing of anchors constructed from cast, forged and fabricated components.

1.1.2 In the context of this Section, the reference to swivels refers to those directly attached to the anchor shank in lieu of the conventional 'D' shackle. For other mooring equipment swivels, *see* 2.13.

1.2 Manufacture

1.2.1 All anchors are to be of an approved design.

1.3 Cast steel anchors

1.3.1 Cast steel anchor heads, shanks, shackles and swivels are to be manufactured and tested in accordance with the requirements of Ch 4,1 and Ch 4,2. The Special grade quality is to be used for anchor heads, shanks and shackles.

1.3.2 Where acid soluble aluminium content is controlled in the range 0,015 per cent to 0,040 per cent, the nitrogen content need not be determined for each cast, provided that random checks are carried out to the satisfaction of LR.

1.3.3 Special consideration will be given to the use of other grades of steel for the manufacture of swivels.

1.3.4 To confirm the quality of cast anchor components, the surveyor may require drop and/or hammering tests to be carried out.

1.3.5 When drop and hammering tests are required, they are to be carried out as follows:

(a) Each anchor, or the components of an anchor made from more than one piece, is to be dropped from a clear height of 4 m onto a steel slab laid on a solid foundation.
(b) Separately cast flukes, shanks and shackles are to be suspended horizontally from a clear height of 4 m before being dropped.
(c) Anchors cast in one piece are to be drop tested twice from a clear height of 4 m. For the first test, the shank and flukes are to be horizontal. For the second test, two steel blocks are to be placed on the slab, arranged so that the middle of each fluke makes contact with the blocks without the crown making contact with the slab, and the orientation of the anchor is to be vertical with the crown nearest the slab.
(d) If the slab is broken by the impact, the test is to be repeated on a new slab.

1.3.6 When hammering tests are required, they are to be carried out after the drop test on each anchor head and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of at least 3 kg mass is to be used.

1.3.7 Repair of fractures or unsoundness detected during the drop or hammering tests are not permitted and the component is to be rejected.

1.4 Forged steel anchors

1.4.1 Forged steel anchor pins, swivels, shanks and shackles are to be manufactured and tested in accordance with the requirements of Ch 5,1 and Ch 5,2 carbon and carbon-manganese steel for welded construction. Rolled steel bar may be used provided that the requirements of Ch 5,1.2.9 are met.

1.4.2 Special consideration will be given to other grades of steel for the manufacture of swivels.

1.5 Fabricated steel anchors

1.5.1 Where it is proposed to use plate material for fabricated steel anchors, it is to comply with the requirements of Ch 3,2 or Ch 3,3, and the proposed manufacturing procedure is to be submitted for approval.

1.5.2 The manufacturing process is to be in accordance with approved welding procedures, using approved welding consumables and carried out by qualified welders.

1.5.3 Stress relief is to be carried out as required in the approved welding procedure.

1.6 Rectification

1.6.1 All rectification is to be agreed with the Surveyor.

1.6.2 Rectification of defective castings is to be carried out in accordance with Ch 4,1.9.

1.6.3 Rectification of defective forgings is to be carried out in accordance with Ch 5,1.9.

1.6.4 Rectification of defective fabricated anchors is to be carried out by suitably qualified welders within the parameters of the approved welding procedure used in construction.

1.7 High holding power (HHP) anchors

1.7.1 Anchor designs for which approval is sought as high holding power anchors are to be tested at sea to show that they have holding powers of at least twice those of approved standard stockless anchors of the same mass.

1.7.2 If approval is sought for a range of sizes, then at least two sizes are to be tested. The smaller of the two anchors is to have a mass not less than one-tenth of that of the larger anchor, and the larger of the two anchors tested is to have a mass not less than one-tenth of that of the largest anchor for which approval is sought.

1.7.3 High holding power anchors are to be of a design that will ensure that the anchors will take effective hold of the sea bed without undue delay and will remain stable, for holding forces up to those required by 1.7.1, irrespective of the angle or position at which they first settle on the sea bed when dropped from a normal type of hawse pipe. In case of doubt, a demonstration of these abilities may be required.

1.7.4 The test should normally be carried out from a tug or other suitable vessel, and the pull measured by dynamometer or derived from recently verified curves of tug rev/min against bollard pull. The tests are to be conducted on not less than three different types of bottom, which should normally be soft mud or silt, sand or gravel, and hard clay or similarly compacted material. A scope of 10 is recommended for the anchor cable, but in no case should a scope of less than 6 be used. The same scope is to be used for the anchor for which approval is sought and the anchor that is being used for comparison purposes.

1.8 Assembly

1.8.1 Assembly and fitting is to be carried out in accordance with the approved design.

1.8.2 Securing of anchor pins, shackle pins or swivels by welding is to be carried out by suitably qualified welders in accordance with an approved welding procedure.

1.9 Proof test of anchors

1.9.1 Anchors having a mass of 75 kg or more inclusive of stock (56 kg in the case of high holding power anchors) are to be tested in the presence of the Surveyor at a proving establishment recognized by LR. A list of recognized proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship or mobile offshore unit is to be registered.

1.9.2 The anchor is to be visually examined before application of the proof test load to ensure that it is free from surface defects of a harmful nature.

1.9.3 As required by 1.9.1, each anchor is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.1.1 for the appropriate mass of the anchor. The proof load is to be applied on the arm or on the palm at a spot which, measured from the extremity of the bill, is one-third of the distance between it and the centre of the crown. For stocked anchors, each arm is to be tested individually. For stockless anchors, both arms are to be tested at the same time, first on one side of the shank, then reversed and tested on the other.

1.9.4 The general arrangements for the test are to be such that the complete anchor, including the shackle, shackle pins and any welded or bolted connections are included in the test. If a replacement shackle is needed which requires welding or heating for fitting, the combined anchor and shackle are to be proof load tested. If welding or heating is not involved in fitting, the shackle may be proof load tested separately from the anchor.

1.9.5 The mass to be used in Table 10.1.1 is:

(a) For stockless anchors, the total mass of the anchor.
(b) For stocked anchors, the mass of the anchor excluding the stock.
(c) For high holding power anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor.
(d) For mooring anchors, including positional mooring anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor, unless specifically agreed otherwise.
(e) For super high holding power anchors, a nominal mass equal to twice the actual total mass of the anchor.

1.9.6 For positional mooring anchors, the proof test loading is to be that required by 1.9.3 or 50 per cent of the minimum break strength of the intended anchor line, whichever is the greater.

1.9.7 The gauge length is to be measured with 10 per cent of the required load applied, before and after proof test. The two measurements shall differ by no more than 1 per cent. The gauge length is the distance between the tip of each fluke and a point on the shank adjacent to the shackle pin, *see* Fig. 10.1.1.

1.10 Non-destructive testing

1.10.1 All parts must have a clean surface consistent with the method of manufacture and be free from cracks, laps, notches, inclusions and other defects which would be detrimental to service performance.

1.10.2 After proof testing all accessible surfaces are to be visually inspected by the Surveyor.

Table 10.1.1 Proof load tests for anchors
(*see* Notes 1 and 2)

Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN
50	23,2	2200	376,0	7800	861,0
55	25,2	2300	388,0	8000	877,0
60	27,1	2400	401,0	8200	892,0
65	28,9	2500	414,0	8400	908,0
70	30,7	2600	427,0	8600	922,0
75	32,4	2700	438,0	8800	936,0
80	33,9	2800	450,0	9000	949,0
90	36,3	2900	462,0	9200	961,0
100	39,1	3000	474,0	9400	975,0
120	44,3	3100	484,0	9600	987,0
140	49,0	3200	495,0	9800	998,0
160	53,3	3300	506,0	10 000	1010,0
180	57,4	3400	517,0	10 500	1040,0
200	61,3	3500	528,0	11 000	1070,0
225	65,8	3600	537,0	11 500	1090,0
250	70,4	3700	547,0	12 000	1110,0
275	74,9	3800	557,0	12 500	1130,0
300	79,5	3900	567,0	13 000	1160,0
325	84,1	4000	577,0	13 500	1180,0
350	88,8	4100	586,0	14 000	1210,0
375	93,4	4200	595,0	14 500	1230,0
400	97,9	4300	604,0	15 000	1260,0
425	103,0	4400	613,0	15 500	1280,0
450	107,0	4500	622,0	16 000	1300,0
475	112,0	4600	631,0	16 500	1330,0
500	116,0	4700	638,0	17 000	1360,0
550	125,0	4800	645,0	17 500	1390,0
600	132,0	4900	653,0	18 000	1410,0
650	140,0	5000	661,0	18 500	1440,0
700	149,0	5100	669,0	19 000	1470,0
750	158,0	5200	677,0	19 500	1490,0
800	166,0	5300	685,0	20 000	1520,0
850	175,0	5400	691,0	21 000	1570,0
900	182,0	5500	699,0	22 000	1620,0
950	191,0	5600	706,0	23 000	1670,0
1000	199,0	5700	713,0	24 000	1720,0
1050	208,0	5800	721,0	25 000	1770,0
1100	216,0	5900	728,0	26 000	1800,0
1150	224,0	6000	735,0	27 000	1850,0
1200	231,0	6100	740,0	28 000	1900,0
1250	239,0	6200	747,0	29 000	1940,0
1300	247,0	6300	754,0	30 000	1990,0
1350	255,0	6400	760,0	31 000	2030,0
1400	262,0	6500	767,0	32 000	2070,0
1450	270,0	6600	773,0	34 000	2160,0
1500	278,0	6700	779,0	36 000	2250,0
1600	292,0	6800	786,0	38 000	2330,0
1700	307,0	6900	794,0	40 000	2410,0
1800	321,0	7000	804,0	42 000	2490,0
1900	335,0	7200	818,0	44 000	2570,0
2000	349,0	7400	832,0	46 000	2650,0
2100	362,0	7600	845,0	48 000	2730,0

Proof loads for intermediate mass are to be determined by linear interpolation

NOTES

1. Where ordinary anchors have a mass exceeding 48 000 kg, the proof loads are to be taken as 2,059 (mass of anchor in kg)$^{2/3}$ kN.
2. Where high holding power anchors have a mass exceeding 36 000 kg, the proof loads are to be taken as 2,452 (actual mass of anchor in kg)$^{2/3}$ kN.

1.10.3 Each cast anchor head, shank, shackle and swivel is to be subjected to magnetic particle or dye penetrant inspection on all surfaces. For ordinary and HHP anchors, where drop and hammering tests have been carried out, the inspection may be restricted to the areas around runners and risers, or where excess material has been removed by thermal methods and weld repairs.

1.10.4 Each casting is to be subjected to ultrasonic inspection in the region of runners and risers, or where excess material has been removed by thermal methods. This examination is to extend around the whole periphery of the casting and for a distance of *t*/3 beyond the area affected, where *t* is the maximum thickness. In addition, random areas are to be selected by the Surveyor and examined.

1.10.5 Ultrasonic testing is not required for ordinary and HHP anchors where drop and hammering tests have been carried out.

1.10.6 All fabrication and repair welds are to be subjected to magnetic particle or dye penetrant inspection.

1.10.7 Paint or anti-corrosive coatings are not to be applied until these inspections are completed to the satisfaction of the Surveyor.

1.11 Clearances and tolerances

1.11.1 Where no fitting tolerances are specified on the approved plans the following assembly and fitting tolerance are to be applied.

1.11.2 The clearance either side of the shank within the shackle jaws and the shackle pin in the shank end hole is to be no more than 3 mm for small anchors up to 3 tonnes, 4 mm for anchors up to 5 tonnes, 6 mm for anchors up to 7 tonnes and is not to exceed 12 mm for larger anchors.

1.11.3 The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle pin to hole tolerance is to be no more than 0,5 mm for pins up to 57 mm and 1,0 mm for pins of larger diameter.

1.11.4 The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1 per cent of the chamber length.

1.11.5 The lateral movement of the shank is not to exceed 3 degrees from the centreline datum, *see* Fig. 10.1.2.

1.12 Identification

1.12.1 All identification marks are to be stamped on one side of the anchor reserved solely for this purpose.

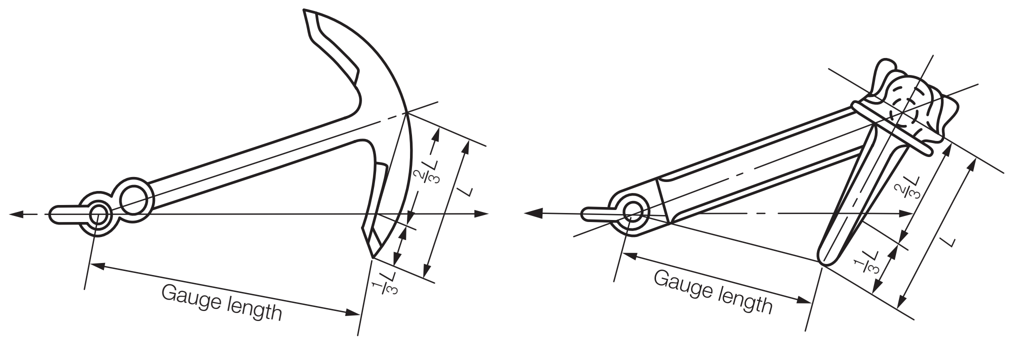


Fig. 10.1.1 Location of gauge length measurement during proof load

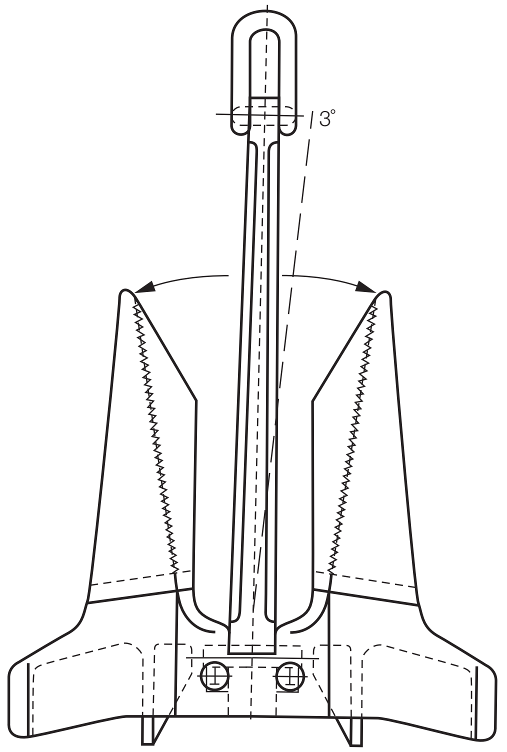


Fig. 10.1.2 Allowable lateral movement of shank

1.12.2 The following details are to be shown on all anchors:

(a) LR or Lloyd’s Register and abbreviated name of LR’s local office issuing the certificate.
(b) Number of the certificate.
(c) Month and year of test.
(d) Mass (also the letters ‘HHP’ when approved as high holding power anchors).
(e) Mass of stock (in the case of stocked anchors).
(f) National Authority requirements, as applicable.
(g) Manufacturer's mark.

1.12.3 In addition to 1.11.2, each important part of an anchor is to be plainly marked by the maker with the words ‘forged steel’ or ‘cast steel’ as appropriate. Fabricated steel anchor heads do not require special marking.

1.13 Certification

1.13.1 The manufacturer is to provide the Surveyor with a written statement that the anchor has been manufactured and tested in accordance with LR Rules together with the following particulars:

(a) Purchaser’s name and order number.
(b) Type of anchor and principal dimensions.
(c) Mass of anchor.
(d) Identification mark which will enable the full history of manufacture to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Proof load.
(j) Results of the non-destructive examination.
(k) Weld repair details (cast steel anchors only).

1.13.2 Shanks, heads, pins, shackles and swivels are to be certified by LR in accordance with the relevant sections of Chapters 3, 4 and 5.

1.13.3 An LR Anchor Certificate is to be issued for the completed anchor which will include the following details:

(a) Manufacturer's name
(b) Type of anchor
(c) Mass of anchor
(d) Grade of materials
(e) Proof test load
(f) Heat treatment
(g) Marking applied to anchor
(h) Dimensions
(j) General Approval of an Anchor Design Certificate Number.

Section 2
Stud link chain cables for ships

2.1 Scope

2.1.1 Provision is made in this Section for a range of grades, U1, U2 and U3, of stud link chain and fittings intended for anchor or mooring cables for ships.

2.1.2 The requirements for offshore mooring chain cables are given in Section 3.

2.2 Manufacture

2.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers of stud link chain cables and fittings is published separately by LR.

2.2.2 The links may be made by the flash-butt or other approved welding process, or in the case of Grades U2 and U3 they may be flash-butt welded or drop forged, designated U2(a) or U3(a), or cast steel designated U2(b) or U3(b), *see* Table 10.2.5.

2.2.3 As far as practicable, consecutive links in all chain cable should originate from a single cast or batch of bar stock (*see* Ch 3,9.6.1), and indicating marks should be stamped on the final link formed from one cast or batch and the first link formed from a separate cast or batch.

2.2.4 A length of chain cable is to measure not more than 27,5 m and is to comprise an odd number of links. In this context, a length is a statutory term and is the basis for the number of test samples.

2.3 Flash butt welded chain cable

2.3.1 Bar material is to comply with the requirements of Ch 3,9 and may be heated either by electrical resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control. The temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and checks are to be recorded.

2.3.2 Mechanical properties testing of U1 cable is not required. For Grade U2 cable supplied in the as-welded condition, and Grade U3 in all conditions, one tensile and one set of three Charpy V-notch impact test specimens are to be taken at the side of a link opposite the weld from at least every fourth 27,5 m length of cable. A further set of three impact test specimens is to be taken with the notch positioned at the centre of the weld, *see* Table 10.2.3. The test specimens are not to be selected from the same length as that from which the breaking test sample is taken, unless breaking test samples are to be taken from every length of the batch. All test samples are to be correctly identified with the lengths of cable represented.

2.3.3 The test links from which the mechanical test specimens are prepared are to be made as part of the chain cable and are to be heat treated with it. They may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents and is subjected to the proof load appropriate to the chain grade and diameter prior to preparation of the mechanical test specimens.

2.3.4 The results of tests on specimens taken from the non-welded areas are to comply with the appropriate requirements of Table 10.2.1. The results of tests on the welds are to comply with the requirements of Table 10.2.6.

2.4 Cast chain cables

2.4.1 The manufacture of cast steel chain cable is generally to be in accordance with the requirements of Ch 4,1, as appropriate.

Table 10.2.1 Mechanical properties of finished chain cable and fittings

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
U2	295	490 – 690	22	—	0 (*see* Note 1)	27
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35

NOTES
1. When required *see* Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C.
3. Mechanical testing is not required for finished chain cables and fittings in Grade U1.

2.4.2 The chemical composition of ladle samples is to comply with the specification approved by LR.

2.4.3 Separately cast test samples are to be provided from each cast. They are to be of similar dimensions to the links they represent and are to be heat treated together with, and in the same manner as, the completed chain cable, *see* Table 10.2.3.

2.4.4 Tensile and Charpy V-notch impact test specimens are to be taken from each test sample and machined to the dimensions given in Ch 2,3.

2.4.5 The results of all tests are to comply with the requirements given in Table 10.2.1 for the relevant grade.

2.5 Forged chain cables

2.5.1 The procedure for the manufacture and testing of drop forgings for chain cable will be specially considered, but is generally to be in accordance with the appropriate requirements of Ch 5,1.

2.5.2 The chemical composition is to comply with Table 10.2.2.

2.5.3 Stock material may be supplied in the as-rolled condition. The completed forgings are to be heat treated in accordance with Table 10.2.3.

2.5.4 Test samples in the form of forgings of similar dimensions to the links they represent and from the same cast and heat treatment charge are to be provided.

Table 10.2.2 Chemical composition of butt welded and forged chain cable

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	N max.	Cr max.	Cu max.	Nb max.	Ni max.	V max.	Mo max.
U1	0,20	0,15 – 0,35	0,40 min.	0,04	0,04	—	—	—	—	—	—	—	—
U2	0,24	0,15 – 0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	—	—	—	—	—	—	—
U3	0,33	0,15 – 0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,015	0,25	0,35	0,05 *see* Note 2	0,40	0,10 *see* Note 2	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

Table 10.2.3 Condition of supply and scope of mechanical tests for finished chain cables and fittings

Grade	Manufacturing method	Condition of supply	Number of test specimens on every four lengths of chain cable of 27,5 m or less, or on each batch of fittings		
			Tensile test on base materials	Charpy V-notch impact test	
				Base material	Weldment
U1 cable	Flash butt welded	As welded Normalized	— —	— —	— —
U2 cable	Flash butt welded	As welded Normalized	1 —	3 —	3 —
U3 cable	Flash butt welded	Normalized Normalized and Tempered Quenched and Tempered	1	3	3
U2 cable	Cast or drop forged	Normalized	1	3	—
U3 cable	Cast or drop forged	Normalized Normalized and Tempered Quenched and Tempered	1	3	—
U2 fittings	Cast or drop forged	Normalized	1	3	—
U3 fittings	Cast or drop forged	Normalized Normalized and Tempered Quenched and Tempered	1	3	—

2.5.5 One tensile and three Charpy V-notch specimens are to be taken from each test sample.

2.5.6 The results of mechanical tests are to comply with the requirements of Table 10.2.1 for the relevant grade.

2.6 Stud material

2.6.1 Steel studs are to be used for all grades of welded chain cable. In general, the carbon content should not exceed 0,23 per cent but mechanical tests for acceptance purposes are not required.

2.7 Welding of studs

2.7.1 Where studs are welded into the links this is to be completed before the chain cable is heat treated.

2.7.2 The stud ends must be a good fit inside the link, and the weld is to be confined to the stud end opposite the flash-butt weld. The full periphery of the stud end is to be welded. If, however, it can be demonstrated to the Surveyor that the quality of welding is of a high standard then partial peripheral welding may be accepted provided that welds are made only at the sides of the stud and that each run extends continuously for at least 25 per cent of the stud periphery.

2.7.3 The welds are to be made by qualified welders using an approved procedure and consumables approved to Grade 3 and low hydrogen.

2.7.4 The welds are to be of good quality and free from defects liable to impair the proper use of the chain. Undercuts, end craters and similar defects shall, where necessary, be ground off.

2.7.5 At least one stud weld within each length of cable is to be inspected using dye penetrant testing after the chain has been proof loaded. If a crack is found, the stud welds in the adjoining links are to be inspected; if a crack is found in either link, all the stud welds in that length are to be inspected using dye penetrant.

2.8 Heat treatment of completed chain cables

2.8.1 The completed chain cable is to be heat treated in accordance with Table 10.2.3 for the appropriate grade of cable.

2.8.2 Special consideration will be given to the heat treatment of certain types of drop forged chain cable.

2.8.3 In all cases, heat treatment is to be carried out prior to the proof loading and breaking tests.

2.8.4 All test samples are to be heat treated with, and in the same way as, the chain cables they represent.

2.9 Testing of completed chain cables

2.9.1 All chain cables are to be subjected to a Proof Load test and a Breaking Load test. In addition, mechanical tests should be carried out where required, *see* Table 10.2.3.

2.9.2 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognized by LR. A list of recognized proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

2.10 Proof load tests

2.10.1 Each length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable.

2.10.2 For test purposes, the cable is to be clean and free from paint and anti-corrosive coatings.

2.10.3 On completion of the test, each link is to be visually examined and is to be free from significant defects. Special attention is to be given to welds.

2.10.4 Should any link be found to be defective it is to be replaced by an approved connecting link (joining shackle or substitute link as detailed in 2.14). The chain is then to be subjected to a repeat of the proof load test followed by re-examination.

2.10.5 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 2.10. If either of these samples fails, the length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected.

2.11 Breaking load tests

2.11.1 Breaking load tests are to be carried out on three-link samples selected by the Surveyor from the completed (including heat treatment) chain. The test links may be removed from the chain prior to heat treatment provided that each sample is heat treated with, and in the same manner as the chain it represents. They are to be properly identified with the lengths of chain they represent.

2.11.2 The number of tests required is to be in accordance with Table 10.2.5 except that for chafing chain for Emergency Towing Arrangements (ETA), *see* Pt 3, Ch 13,9.2, one test is to be carried out on each 110 m of finished chains.

Table 10.2.4 Test loads for stud link anchor chain cables

Chain diameter	Grade U1		Grade U2		Grade U3	
	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN
d mm	$0{,}00686d^2(44-0{,}08d)$	$0{,}00981d^2(44-0{,}08d)$	$0{,}00981d^2(44-0{,}08d)$	$0{,}01373d^2(44-0{,}08d)$	$0{,}01373d^2(44-0{,}08d)$	$0{,}01961d^2(44-0{,}08d)$
12,5	46	66	66	92	–	–
14	58	82	82	115	–	–
16	75	107	107	150	–	–
17,5	89	128	128	179	–	–
19	105	150	150	211	–	–
20,5	122	175	175	244	244	349
22	140	201	201	281	281	401
24	166	238	238	333	333	475
26	194	278	278	389	389	556
28	225	321	321	450	450	642
30	257	367	367	514	514	734
32	291	416	416	583	583	832
34	327	468	468	655	655	936
36	366	523	523	732	732	1045
38	406	580	580	812	812	1160
40	448	640	640	896	896	1280
42	492	703	703	984	984	1406
44	538	769	769	1076	1076	1537
46	585	837	837	1171	1171	1673
48	635	908	908	1270	1270	1814
50	686	981	981	1373	1373	1961
52	739	1057	1057	1479	1479	2113
54	794	1135	1135	1589	1589	2269
56	850	1216	1216	1702	1702	2430
58	908	1299	1299	1818	1818	2597
60	968	1384	1384	1938	1938	2767
62	1029	1472	1472	2060	2060	2943
64	1092	1562	1562	2187	2187	3123
66	1157	1655	1655	2316	2316	3308
68	1223	1749	1749	2448	2448	3496
70	1291	1846	1846	2583	2583	3690
73	1395	1995	1995	2792	2792	3988
76	1503	2149	2149	3007	3007	4295
78	1576	2254	2254	3154	3154	4505
81	1689	2415	2415	3380	3380	4827
84	1805	2580	2580	3612	3612	5158
87	1923	2750	2750	3849	3849	5498
90	2045	2924	2924	4093	4093	5845
92	2127	3042	3042	4258	4258	6081
95	2254	3223	3223	4510	4510	6442
97	2339	3345	3345	4682	4682	6687
100	2470	3532	3532	4943	4943	7060
102	2558	3658	3658	5120	5120	7312
105	2692	3850	3850	5389	5389	7697
107	2783	3980	3980	5571	5571	7957
111	2968	4245	4245	5941	5941	8486
114	3110	4447	4447	6224	6224	8889
117	3253	4652	4652	6511	6511	9299
120	3398	4859	4859	6801	6801	9714
122	3496	4999	4999	6997	6997	9994
124	3595	5141	5141	7195	7195	10276
127	3744	5354	5354	7494	7494	10703
130	3895	5571	5571	7796	7796	11135
132	3997	5716	5716	8000	8000	11426
137	4254	6083	6083	8514	8514	12161
142	4515	6456	6456	9036	9036	12906
147	4779	6834	6834	9565	9565	13662
152	5046	7217	7217	10100	10100	14426
157	5316	7602	7602	10640	10640	15197
162	5588	7991	7991	11185	11185	15975

Table 10.2.5 Number of breaking tests from completed cables

Designation	Method of manufacture	Number of breaking test specimens
Grade U1	Flash-butt welded and heat treated	One from every four lengths of 27,5 m or less
Grade U2(a) U3(a)	Flash-butt welded, or drop forged and heat treated	One from every four lengths of 27,5 m or less
Grade U1 U2(a)	Flash-butt welded but not heat treated	One from each length of 27,5 m or less
Grade U2(b) U3(b)	Cast and heat treated	One per heat treatment batch with a minimum of one from every four lengths of 27,5 m or less

Table 10.2.6 Mechanical properties of welds in chain cables

Grade	Charpy V-notch impact test	
	Test temperature °C	Average energy J min
U1	—	—
U2	0 (*see* Note 1)	27
U3	0	50
	–20 (*see* Note 2)	27

NOTES
1. Impact tests are only required if the chain cable is not heat treated.
2. Impact testing may be carried out at 0°C or minus 20°C.

2.11.3 Breaking test specimens are to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load for a minimum of 30 seconds.

2.11.4 Where a breaking test specimen fails, a further specimen is to be cut from the same length of cable and subjected to test. If this re-test fails, the length of cable from which it was taken is to be rejected. When this test is also representative of other lengths, each of the remaining lengths is to be individually tested by taking a breaking test specimen from each length of the batch. If one of these further tests fails, the entire set of lengths represented by the original test is to be rejected.

2.11.5 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

2.12 Dimensional inspection

2.12.1 After proof testing, the entire chain is to be checked for length, five links at a time with an overlap of two links, to ensure that the chain meets the tolerances given in 2.15.4. The measurements are to be made while the chain is loaded to about 10 per cent of the proof load.

2.12.2 The links held in the end blocks may be excluded from these measurements.

2.12.3 If a five link length of chain exceeds the tolerance given in 2.15.4, the oversize links are to be removed and an approved connecting link inserted.

2.12.4 Checks of all other dimensions are to be made on three links, selected by the Surveyor, from every four 27,5 m lengths.

2.12.5 If one of the links detailed in 2.12.4 fails to comply with the required tolerances, measurements are to be made on a further five links in every four 27,5 m lengths.

2.12.6 If more than one link in a 27,5 m length of chain cable fails to meet the tolerance requirements, all the links in that length are to be measured.

2.12.7 All links failing to comply with the maximum dimensional tolerances are to be removed and replaced by connecting links of an approved type. The chain is then to be subjected to a further proof load test and re-examined.

2.13 Fittings for chain cables

2.13.1 Cable fittings are to be manufactured at an approved works.

2.13.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1 respectively. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

2.13.3 All fittings are to be manufactured to an approved manufacturing specification, and provision is to be made for tensile specimens and, where applicable, impact test specimens, *see* Table 10.2.3. The test samples are to be prepared in accordance with 2.4.3 or 2.5.4 as applicable. The test specimens are to be subjected to heat treatment with the fittings they represent. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.2.1. A batch of fittings is to be of the same grade, size and heat treatment charge and to have originated from a single cast of steel. Enlarged and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

2.13.4 Fittings such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade U2. The welded construction of fittings may also be approved providing that full details of the manufacturing process and the heat treatment are submitted.

2.13.5 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended. These include shackles, swivels, swivel shackles, enlarged links and end links. Anchor shackles, however, are to be tested in combination with the anchor, *see* 1.3.9.

2.13.6 The appropriate breaking load is to be applied for a minimum of 30 seconds to at least one item out of every batch of up to 25 (1 in 50 for lugless (Kenter) shackles), and this item is to be destroyed and not used as part of an outfit. For the purpose of break load testing, a batch of accessories is to be of the same grade, size and heat treatment charge and may consist of items from different casts, provided that the sample tested is from the cast with the lowest tensile properties. Enlarged and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

2.13.7 If the sample fails to withstand the breaking load without fracture, two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

2.13.8 Where the items are of increased dimensions, and have been specially approved, or if material of a higher grade than is specified is used the breaking load may be applied to each item, and the items so tested included with the outfit. For the purpose of this paragraph, items of increased dimensions are those so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load of the chain cable with which they are to be used.

2.13.9 LR may waive the breaking load test provided that:
(a) the breaking load test has been completed satisfactorily during approval testing, and
(b) the tensile and impact properties of each manufacturing batch are proved and
(c) the accessories are subjected to suitable non-destructive testing.

2.13.10 All testing is to be carried out in the presence of the Surveyor and to his satisfaction.

2.13.11 All fittings are to be stamped in accordance with 2.16.

2.14 Substitute single links

2.14.1 Single links to connect lengths of chain cable or to substitute for defective links, without the necessity for re-heat treatment of the whole cable length, are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and the tests are to be made on the maximum size of chain for which approval is sought. Re-approval is required annually.

2.14.2 Manufacture and heat treatment of the substitute link are not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

2.14.3 The steel bar used is to conform with the specification for the chain in accordance with Ch 3,9.

2.14.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

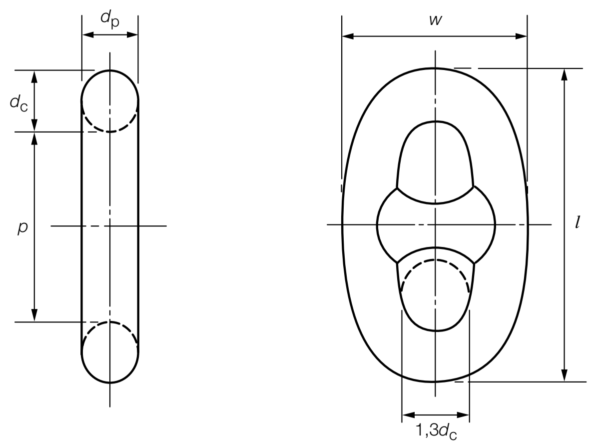
2.14.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

2.14.6 Every substitute link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated, as detailed in Table 10.2.4.

2.14.7 Each substitute link is to be stamped on the stud with the identification marks listed in 2.16.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.

2.15 Dimensions and tolerances

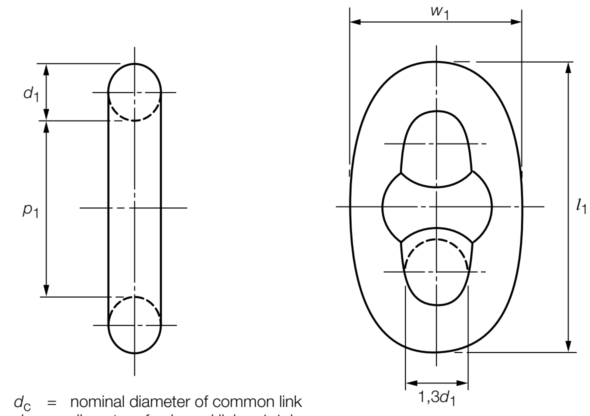
2.15.1 The form and proportion of links and shackles are to be in accordance with ISO/1704-1991, *see* Figs. 10.2.1 to 10.2.6.



d_c = nominal diameter at crown measured in plane of link
d_p = nominal diameter at crown measured perpendicular to plane of link
l = $6d_c$
p = $4d_c$
w = $3{,}6d_c$ to the nearest millimetre

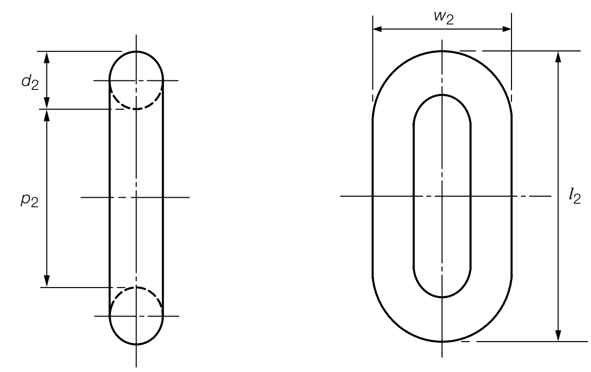
Fig. 10.2.1 Common link

2.15.2 Manufacturing tolerances on stud link chain are to be within ±2,5 per cent (taking into account that all components of the chain are to be a good fit with one another), except for those detailed in 2.15.3.



d_c = nominal diameter of common link
d_1 = diameter of enlarged link = $1{,}1d_c$
l_1 = $6d_1$
p_1 = $4d_1$
w_1 = $3{,}6d_1$

Fig. 10.2.2 Enlarged link



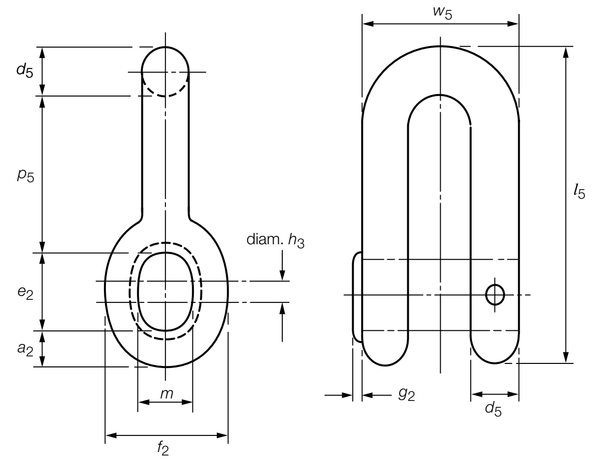
d_c = nominal diameter of common link
d_2 = diameter of end link = $1{,}2d_c$
l_2 = $p_2 + 2d_2 = 6{,}75d_c$
p_2 = $4{,}35d_c$
w_2 = $4d_c$

Fig. 10.2.3 End link

2.15.3 The cross-sectional area at the crown of the link is to have no negative tolerance. The negative tolerance on the diameter at the crown measured in the plane of the link is not to exceed:

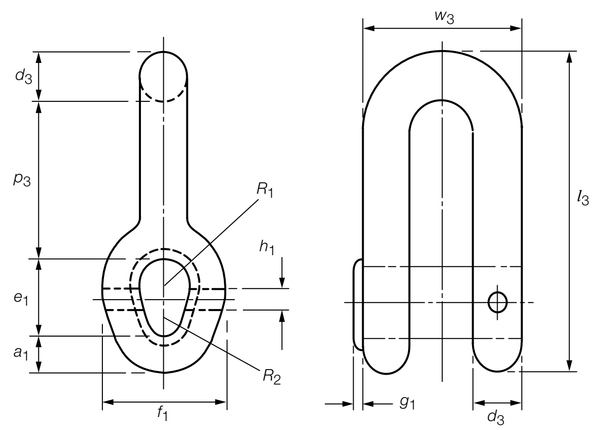
Minus 1 mm when $d_c \leq 40$ mm
Minus 2 mm when 40 mm $< d_c \leq 84$ mm
Minus 3 mm when 84 mm $< d_c \leq 122$ mm
Minus 4 mm when $d_c > 122$ mm

The plus tolerance on the diameter at the crown measured out of the plane of the link is not to exceed 5 per cent. The cross-sectional area is to be calculated using the average of the diameter measured in the plane of the link d_c, *see* Fig. 10.2.1, and the diameter measured perpendicular to the plane of the link, d_p.



d_c = nominal diameter of common link
d_5 = diameter of end shackle = $1{,}4d_c$
l_5 = $8{,}7d_c$
p_5 = $l_5 - (d_5 + a_2 + e_2)^2\ 4{,}6d_c$
w_5 = $5{,}2d_c$
a_2 = $0{,}9d_c$
e_2 = $1{,}8d_c$
f_2 = $3{,}1d_c$
g_2 = $0{,}2d_c$
h_3 = $0{,}4d_c$
m = $1{,}4d_c$

Fig. 10.2.4 End shackle



d_c = nominal diameter of common link
d_3 = diameter of joining shackle = $1{,}3d_c$
l_3 = $7{,}1d_c$
p_3 = $l_3 - (d_3 + a_1 + e_1) = 3{,}4d_c$
w_3 = $4d_c$
a_1 = $0{,}8d_c$
e_1 = $1{,}6d_c$
f_1 = $2{,}8d_c$
g_1 = $0{,}2d_c$
h_1 = $0{,}4d_c$
R_1 = $0{,}6d_c$
R_2 = $0{,}5d_c$

Fig. 10.2.5 Dee shackle

2.15.4 The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance is to be in accordance with Table 3.9.3 of Chapter 3 except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR.

2.15.5 The maximum allowable tolerance on a length of five links measured in accordance with 2.12.1 is plus 2,5 per cent. No under-tolerance is permitted.

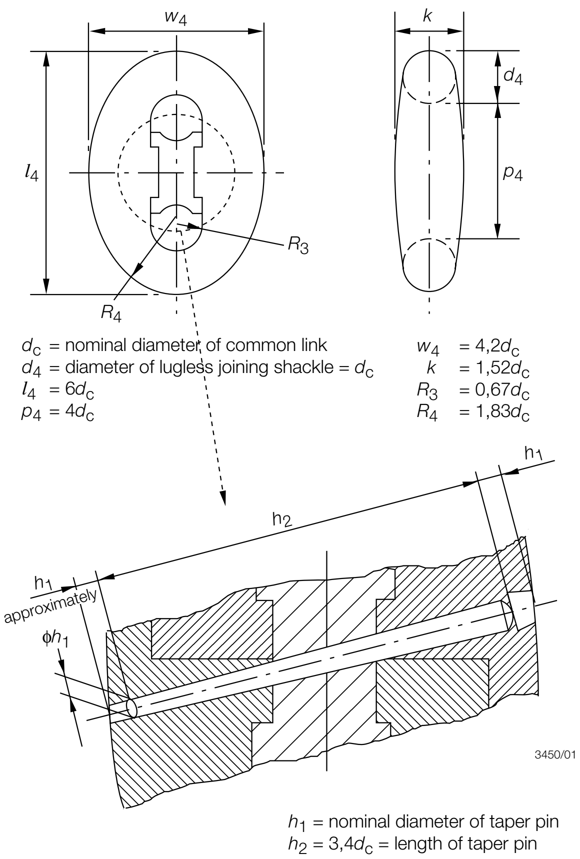


Fig. 10.2.6 Lugless shackle

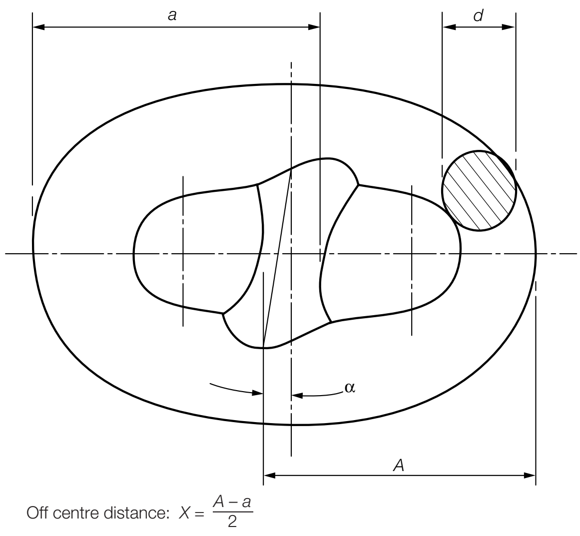


Fig. 10.2.7 Stud dimensions

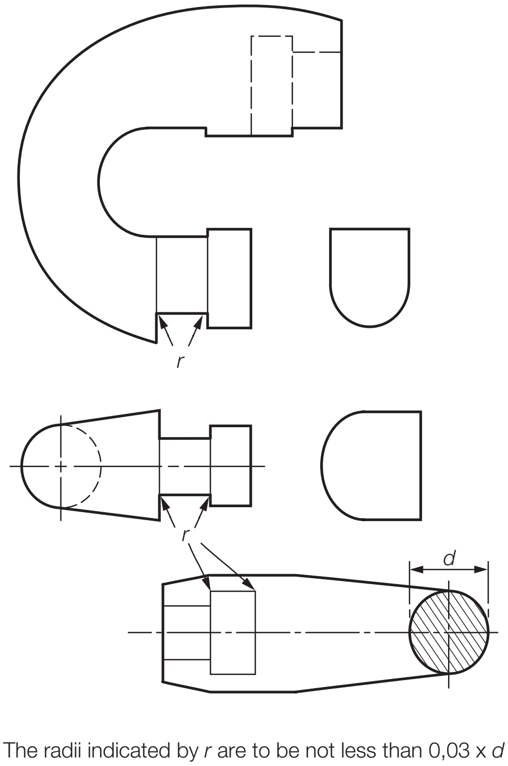


Fig. 10.2.8 Lugless shackle of the Kenter type

2.15.6 All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

2.15.7 Studs are to be located in the links centrally, and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The following tolerances are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link:

Maximum off-centre distance X: 10 per cent of the nominal diameter, d

Maximum deviation, α from the 90° position: 4°

The tolerances are to be measured in accordance with Fig. 10.2.7.

2.15.8 The following tolerances are applicable to accessories:

Nominal diameter: plus 5 per cent, minus 0 per cent

Other dimensions: ±2,5 per cent.

2.15.9 For lugless shackles of the Kenter type, the radii indicated in Fig. 10.2.8 are to be not less than 0,03 times the chain diameter.

2.15.10 All materials are to be free from internal and surface defects that might impair proper workability, use and strength. Subject to agreement by the Surveyor, surface defects may be removed by grinding provided the acceptable tolerances are not exceeded.

2.16 Identification

2.16.1 All lengths of Grades U1, U2 and U3 cable and all fittings are to be stamped with the following identification marks:

(a) LR or Lloyd's Register and abbreviated name of LR's local office issuing the certificate.
(b) Number of certificate.
(c) Proof load and grade of chain.

2.17 Certification

2.17.1 Certificates may be issued for chain cable only, fittings only or chain cable with associated fittings.

2.17.2 The test certificate is to include the following particulars for all items included on the certificate:

(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Grade of chain cable.
(d) Identification mark which will enable the full history of the chain or fitting to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Breaking test load.
(j) Proof load.

2.17.3 Where appropriate, the certificate is to include a list of all substitute links together with their grade of steel, the name of the steelmaker, the heat number and the purchase order number.

■ *Section 3* **Stud link mooring chain cables**

3.1 Scope

3.1.1 Provision is made in this Section for three grades, R3, R3S and R4, of stud link chain intended for offshore mooring applications such as mooring of mobile offshore units, offshore loading systems and gravity based structures during fabrication.

3.1.2 In addition, chain cable conforming to the requirements of the current edition of API specification 2F is acceptable provided that it has been manufactured, inspected and tested under Survey by LR, and that the bar stock has also been certified by LR in accordance with Ch 3,9.

3.2 Manufacture

3.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers for stud link chain cables is published separately by LR.

3.2.2 The works in which the chain is manufactured is to have a quality system approved by LR. The provision of such a quality system is required in addition to and not in lieu of the witnessing of tests by a Surveyor.

3.2.3 Approval is confined to a single works and is limited to one grade of cable made from bar from a nominated and approved supplier. Separate approvals are required if steel bar is supplied from more than one works and for other grades of cable, *see also* Ch 3,9.

3.2.4 Drawings showing the detailed design of the chain and accessories made by or supplied through the chain manufacturer are to be submitted for approval. These are to include details showing the design of the studs.

3.2.5 Details of the method of manufacture and the specification of the steel, are to be submitted.

3.2.6 Offshore mooring chains are to be made in continuous lengths by flash-butt welding.

3.2.7 Bar material may be heated either by electric resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control and the temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and records taken.

3.2.8 The following welding parameters are to be controlled during welding of each link:

(a) platen motion,
(b) current as a function of time.

The controls are to be checked at least once every four hours.

3.2.9 The records of bar heating, flash-butt welding and heat treatment are to be made available to the Surveyor when required.

3.2.10 As far as practicable, consecutive links in all chain cable should originate from a single batch of bar stock (*see* Ch 3,9.6.1) and indicating marks should be stamped on the final link formed from one batch and the first link formed from a separate batch.

3.2.11 Dimensions and tolerances are to comply with 2.15.

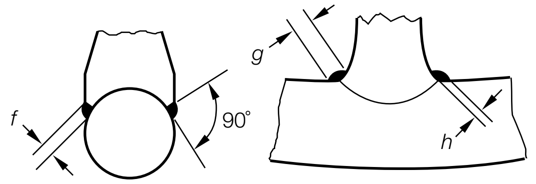
3.3 Studs

3.3.1 The studs are to be made of steel corresponding to that of the chain or in compliance with a specification approved by LR. In general, the carbon content should not exceed 0,23 per cent if the studs are to be welded in place.

3.3.2 Studs may be welded into grade R3 and R3S chains. The welding of studs into grade R4 chain is not permitted unless especially approved.

3.3.3 In all cases where studs are welded into links, this is to be carried out in accordance with 2.6.

3.3.4 The size of the stud welds is to be in accordance with Fig. 10.3.1.



Dimension Designation	Nominal Dimension	Minus Tolerance
f	0,10*d*	0,01*d*
g	0,20*d*	0,02*d*
h	0,09*d*	0,01*d*

d = Nominal diameter of barstock

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Fig. 10.3.1
Dimensions and tolerances of stud welds

3.3.5 All stud welds are to be visually inspected. At least 10 per cent of all stud welds within a 100 m length are to be examined by dye penetrant or magnetic particle inspection after proof load testing. Cracks or lack of fusion are not acceptable; if any such defects are found, all stud welds in that 100 m length are to be examined by means of dye penetrant or magnetic particle inspection.

3.3.6 Where plastic straining is used to set studs, the applied load is not to be greater than that qualified in approval tests. The combined effect of shape and depth of the impression of the stud in the link is not to cause any harmful notch effect or stress concentration.

3.4 Heat treatment of completed chain cables

3.4.1 The chain is to be normalized, normalized and tempered or quenched and tempered in accordance with the specification approved by LR.

3.4.2 The chains are to be heat treated in a continuous furnace; batch heat treatment is not permitted.

3.4.3 The temperature and time, or chain speed, are to be controlled and continuously recorded.

3.4.4 Heat treatment is to be carried out prior to the proof loading and breaking tests.

3.4.5 Calibration of furnaces is to be verified by measurement and recording of actual link temperature (surface and internal).

3.5 Testing of completed chain cables

3.5.1 The entire length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable.

3.5.2 Care should be taken to obtain a uniform stress distribution in the links being tested.

3.5.3 The chain is to be shot blasted in order to ensure that its surfaces are free from scale, paint or other coating for inspection. This may be immediately before or after proof loading at the discretion of the manufacturers.

3.5.4 On completion of the proof load test, each link is to be visually examined and is to be free from significant defects such as mill defects, surface cracks, dents and cuts, especially where gripped by clamping dies during flash butt welding. Studs are to be securely fastened and any burrs, irregularities and rough edges are to be removed by careful grinding.

3.5.5 All flash butt welds, including the area gripped by the clamping dies are to be examined by magnetic particle inspection. The area is to be free from cracks, lack of fusion and gross porosity.

3.5.6 Surface defects in the region of the flash butt welds may be removed by grinding, provided that the depth of grinding does not exceed five per cent of the link diameter and is smoothly contoured into the surrounding material. The final dimensions are still to conform with the agreed standard.

3.5.7 All flash butt welds are also to be examined by ultrasonic inspection and are to be free from defects such as internal cracks or lack of fusion.

3.5.8 After proof testing, the entire chain is to be checked for length, five links at a time with an overlap of two links, to ensure that the chain meets the tolerances given in 2.15.5. The measurements are to be made while the chain is loaded to about 10 per cent of the proof load.

3.5.9 The links held in the end blocks may be excluded from these measurements.

3.5.10 If the length over five links is less than the nominal, the chain may be stretched by loading above the specified proof test load provided that the applied load is not greater than that approved and that only random lengths of the chain need to be stretched.

3.5.11 Checks of all other dimensions are to be made on at least five per cent of the links in the cable.

3.5.12 If any link fails to meet the dimensional tolerance requirements (*see* 2.15), measurements are to be made on 20 more links on each side of the incorrect one. If failure to meet any particular dimensional requirements occurs in more than two of the measured links, then all the links are to be dimensionally checked.

Table 10.3.1 Test loads for mooring chain cables

Chain diameter	Grade R3			Grade R3S			Grade R4		
	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load
	Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain	
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN
50	1480	1560	2230	1800	1740	2490	2160	1920	2740
52	1590	1680	2400	1940	1880	2680	2330	2070	2960
54	1710	1810	2580	2080	2020	2880	2500	2220	3170
56	1830	1940	2760	2230	2160	3090	2680	2380	3400
58	1960	2070	2950	2380	2310	3300	2860	2540	3630
60	2090	2200	3150	2540	2460	3510	3050	2710	3870
62	2220	2340	3350	2700	2620	3740	3240	2880	4110
64	2360	2490	3550	2870	2780	3970	3440	3050	4360
66	2500	2630	3760	3040	2940	4200	3640	3240	4620
68	2640	2780	3980	3210	3110	4440	3850	3420	4890
70	2790	2940	4200	3390	3280	4690	4060	3610	5160
73	3010	3170	4540	3660	3540	5060	4390	3900	5570
76	3240	3420	4880	3940	3820	5450	4730	4200	6000
78	3400	3590	5120	4140	4000	5720	4960	4410	6300
81	3640	3840	5490	4430	4290	6130	5320	4720	6750
84	3890	4110	5870	4740	4590	6550	5680	5050	7210
87	4150	4380	6250	5050	4890	6980	6060	5380	7680
90	4410	4650	6650	5370	5200	7420	6440	5720	8170
92	4590	4840	6920	5580	5410	7720	6700	5950	8500
95	4860	5130	7330	5910	5730	8180	7100	6300	9000
97	5050	5320	7600	6140	5940	8490	7370	6540	9340
100	5330	5620	8030	6480	6280	8960	7780	6910	9860
102	5520	5820	8320	6710	6500	9290	8050	7150	10220
105	5810	6130	8750	7070	6840	9770	8480	7530	10750
107	6010	6330	9050	7300	7070	10100	8760	7780	11120
111	6400	6760	9650	7790	7540	10780	9350	8300	11860
114	6710	7080	10110	8160	7900	11290	9790	8690	12420
117	7020	7400	10570	8540	8270	11810	10240	9100	12990
120	7330	7730	11050	8920	8630	12330	10700	9500	13570
122	7540	7960	11370	9170	8880	12690	11010	9780	13960
124	7750	8180	11690	9430	9130	13050	11320	10050	14360
127	8080	8520	12170	9820	9510	13590	11790	10470	14960
130	8400	8860	12660	10220	9900	14140	12270	10890	15560
132	8620	9100	12990	10490	10160	14510	12590	11180	15970
137	9180	9680	13830	11160	10810	15440	13400	11890	16990
142	9740	10270	14680	11850	11470	16390	14220	12620	18030
147	10310	10880	15540	12540	12140	17350	15050	13360	19090
152	10890	11480	16410	13240	12820	18320	15890	14110	20160
157	11470	12100	17280	13950	13510	19300	16740	14860	21230
162	12060	12720	18170	14660	14200	20280	17600	15620	22320

3.5.13 Should any link be found to be defective or fail to meet the dimensional tolerance requirements or if a five link length of chain exceeds the specified tolerance, the unsatisfactory links are to be removed from the chain, and connecting common links complying with the requirements of 3.6 inserted in their places.

3.5.14 The chain is then to be subjected to a further proof load test and re-examined.

3.5.15 The number of connecting common links which may be used to replace defective links is not to exceed three in any 100 m length of chain. The number and type of joining shackles which may be used are to be subject to the written agreement of the end user.

3.5.16 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 3.5.17 and 3.5.18. If either of these samples fails, the proof loaded length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected and also the possibility that similar factors to those which caused the failure may also be present in other parts of the cable.

3.5.17 In addition to the requirements of 3.5.1, three link samples are to be selected by the Surveyors from the completed chain for breaking tests. The number of tests required is to be in accordance with Table 10.3.2. Extra links are to be provided for the mechanical tests detailed in 3.5.21. All test links are to be made as part of the chain cable and are to be heat treated with it. These may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents and is subjected to the proof load appropriate to the chain grade and diameter prior to selection of the mechanical test specimens. They are to be properly identified with the length of chain they represent.

Table 10.3.2 Frequency of break and mechanical tests

Nominal chain diameter mm	Maximum sampling interval m (*See* Note)
Min — 48	91
49 — 60	110
61 — 73	131
74 — 85	152
86 — 98	175
99 — 111	198
112 — 124	222
125 — 137	250
138 — 149	274
150 — 162	297
163 — 175	322

NOTE
If the sampling interval contains links made from more than one cast, extra break and mechanical tests are required so that tests are made on every cast.

3.5.18 Breaking test specimens are to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable for a period of 30 seconds. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load.

3.5.19 If a breaking test specimen fails, two further specimens are to be cut from the same sampling length and both are to be subjected to the breaking test load. If one of the re-test specimens fails the length is to be rejected. All the broken links are to be subjected to an investigation into the cause of failure. LR will then decide which lengths of chain can be accepted and on further action.

3.5.20 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

3.5.21 One tensile and three sets of Charpy V-notch impact test specimens are to be taken from links cut from the heat treated and proof loaded chain at intervals no greater than those indicated in Table 10.3.2 provided that every cast is sampled. The tensile specimen and one set of impact specimens are to be taken from the side of the link opposite the weld. One set of impact test specimens is to have the notches positioned at the centre of the flash butt weld and the third set is to be taken from the bend. All the specimens are to be taken from positions in accordance with Fig. 3.1.1(f) in Chapter 3.

3.5.22 The frequency of testing at the link bends may be reduced at the discretion of LR provided it can be verified that the required toughness is achieved consistently.

3.5.23 The results of the mechanical tests are to comply with the requirements of Table 10.3.3.

Table 10.3.3 Mechanical properties of chain cable materials

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation % minimum	Reduction of area % minimum (*See* Note 3)	Charpy V-notch impact tests		
					Test temperature °C	Average energy J minimum	Average energy flash weld J minimum
R3	410 (*See* Note 1)	690 minimum (*See* Note 1)	17	50	0 –20 (*See* Note 2)	60 40	50 30
R3S	490 (*See* Note 1)	770 minimum (*See* Note 1)	15	50	0 –20 (*See* Note 2)	65 45	53 33
R4	580 (*See* Note 1)	860 minimum (*See* Note 1)	12	50	–20	50	36

NOTES
1. The ratio of yield strength to tensile strength should not exceed 0,92.
2. Testing may be carried out at either 0°C or –20°C.
3. For cast accessories, the minimum values for reduction of area are to be 40% for Grades R3 and R3S and 35% for Grade R4.

3.5.24 If the tensile test requirements are not achieved, two further specimens from the same sample are to be tested. The related length of chain will be considered acceptable if both re-test specimens meet the requirements but failure of either of the re-test specimens will result in rejection of the sampling length of chain represented by the tests.

3.5.25 If the impact test requirements are not achieved, re-tests may be carried out in accordance with Ch 1,2.4. Failure to meet the re-test requirements will result in rejection of the sampling length of chain represented by the tests.

3.6 Connecting common links or substitute links

3.6.1 Single links to connect lengths of heat treated chain cable or to substitute for test links or defective links without the necessity for re-heat treatment of the whole length of cable are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and tests are to be made on the maximum size of chain for which approval is sought.

3.6.2 Manufacture and heat treatment of the connecting common link is not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

3.6.3 The steel bar used is to conform with the specification for the chain and approved by LR in accordance with Ch 3,9.

3.6.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

3.6.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

3.6.6 Every connecting common link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated as detailed in Table 10.3.1.

3.6.7 Every connecting common link is to be inspected in accordance with 3.5.4 to 3.5.7.

3.6.8 A second identical link is to be made for mechanical tests which are to be in accordance with 3.5.21. This test link is also to be inspected in accordance with 3.6.7.

3.6.9 Each connecting common link is to be stamped on the stud with the identification marks listed in 3.8.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.

3.7 Fittings for offshore mooring chain

3.7.1 Cable fittings are to be manufactured at an approved works.

3.7.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

3.7.3 All fittings are to be manufactured to a manufacturing specification approved by LR, and provision is to be made for tensile and impact test specimens. The test samples are to be subjected to heat treatment with the fittings they represent. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.3.3, except that for castings the minimum required Reduction of Area is 40 per cent for Grades R3 and R3S and 35 per cent for Grade R4.

3.7.4 Manufacturers intending to supply accessories in the machined condition (e.g. Kenter type shackles) are to submit detailed drawings for approval by LR.

3.7.5 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended, *see* Table 10.3.1. Prior to this test, the accessories are to be shot or sand blasted to ensure that their surfaces are free from scale, paint or any other coating which could interfere with any subsequent inspection.

3.7.6 The proof load test is to be carried out in the presence of the Surveyor but if the manufacturer has a procedure for recording proof loads and the Surveyor is satisfied with the adequacy of the recording system, he need not witness all proof load tests.

3.7.7 The appropriate breaking load as required by Table 10.3.1 is to be applied to at least one item out of every batch of up to 25, and this item is to be destroyed and not used as part of an outfit. A batch of accessories is to be of the same grade, size and heat treatment charge and to have originated from a single cast of steel.

3.7.8 If the sample fails to withstand the breaking load without fracture, two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

3.7.9 For very large fittings where the required breaking load is greater than the capacity of the testing machine and for individually produced accessories or accessories produced in small batches, proposals for an alternative method of testing will be given special consideration.

3.7.10 At least one accessory from each batch is to be checked dimensionally after proof load testing. The manufacturer is to provide a statement that the dimensions comply with the specified requirements.

3.7.11 All accessories are to be subjected to close visual examination after proof load testing, particular attention being paid to machined surfaces and highly stressed regions. All accessories are also to be examined by magnetic particle or dye penetrant inspection and ultrasonic testing. The manufacturer is to provide a statement that the non-destructive examination has been carried out with satisfactory results.

3.7.12 In the event of a failure of any test, the entire batch is to be rejected unless the cause of failure has been determined and it can be demonstrated that the condition causing failure is not present in any of the other accessories in the batch.

3.7.13 Except as indicated in 3.7.6, all testing is to be carried out to the satisfaction and in the presence of the Surveyor.

3.8 Identification

3.8.1 Each length of chain is to be permanently marked with the following:

(a) LR and abbreviated name of LR's local office issuing the certificate.
(b) Certificate number (this may be abbreviated provided it is stated in the certificate).
(c) Grade and proof load of chain.

3.8.2 The chain is to be marked as follows:

(a) at each end (the marking should identify the leading and tail end of each chain),
(b) at intervals not exceeding 100m,
(c) on all connecting common links or shackles and the immediately adjacent links,
(d) on the first and last common link of each individual charge used in the continuous length.

3.8.3 All identification marks are to be made on the studs and are to be permanent and legible throughout the expected service life of the chain.

3.9 Certification

3.9.1 Individual certificates are to be issued for each continuous single length of chain.

3.9.2 The test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Grade of chain cable.
(d) Identification mark which will enable the full history of the chain to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Breaking test load.
(j) Proof load.
(k) The number and locations of all connecting common links and all marked links.

3.10 Documentation

3.10.1 A complete Chain Inspection and Testing Report, in booklet form, is to be provided by the chain manufacturer for each continuous chain length. It is to include all dimensional checks, test and inspection reports, non-destructive test reports, process records as well as any non-conformities together with corrective action and repair work.

3.10.2 All documents, including reports and appendices are to carry a reference to the relevant certificate number.

3.10.3 The chain manufacturer is responsible for storing all the documentation in a safe and retrievable manner for a period of at least 10 years.

3.10.4 An Inspection and Testing Report, in booklet form, is to be provided for each order. This is to include all reports of tests, inspections and dimensional measurements and all non-conformities together with corrective or repair action taken. Each type of accessory is to be covered by a separate certificate. All accompanying documents are to carry a reference to the relevant certificate number. The manufacturer is responsible for storing all documentation for a period of at least 10 years in a safe and retrievable manner.

■ *Section 4*
Studless mooring chain cables

4.1 Scope

4.1.1 Provision is made in this Section for three grades, R3, R3S and R4, of studless flash butt welded chain cable intended for long term mooring applications.

4.1.2 The chain is generally expected to be deployed only once for a pre-determined service life.

4.1.3 Each studless chain link design will require to be approved by LR. The plan submitted for this approval is to include the minimum proof and breaking test loads.

4.2 Manufacture

4.2.1 All the requirements of 3.2, with the exception of that relating to studs (3.2.4), apply to the manufacture of studless mooring chain cables.

4.3 Shape and dimensions of links

4.3.1 The shape and dimensions of the links are to be in accordance with the approved design.

4.4 Dimensional tolerances

4.4.1 The dimensional tolerances of studless links are to be in accordance with the requirements of 2.15.2 to 2.15.6.

4.5 Heat treatment

4.5.1 Heat treatment of the chain is to be in accordance with the requirements of 3.4.

4.6 Testing of completed chain

4.6.1 The entire length of chain cable is to be subjected to a proof load test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and diameter of the chain, *see also* 4.1.3.

4.6.2 Inspection after proof load testing is to be in accordance with the requirements given in 3.5.2 to 3.5.16, excluding that related to studs in 3.5.4.

4.6.3 In addition to the inspection of the flash butt welded areas as required in 3.5.5, the surfaces of the bends of at least 10 per cent of the links are to be examined by magnetic particle inspection and are to be free from cracks or other defects.

4.6.4 If stretching of links is required in order to maintain dimensional tolerances (*see* 3.5.10), the load applied is not to exceed the proof load by more than 10 per cent.

4.6.5 Breaking load tests are to be carried out in accordance with 3.5.17 to 3.5.19 and Tables 10.3.1 and 10.3.2.

4.6.6 Alternative procedures to breaking load testing (*see* 3.5.20) are not permissible unless prior agreement is given by LR after special consideration.

4.6.7 Mechanical testing is to be carried out in accordance with 3.5.21 to 3.5.25 and Table 3.3.3.

4.7 Connecting or substitute links

4.7.1 Connecting links and substitute links are to be in accordance with the requirements of 3.6.

4.8 Fittings

4.8.1 Fittings for studless chain are to comply with the requirements of 3.7.

4.9 Identification

4.9.1 All chain is to be identified in accordance with 3.8.1 and 3.8.2.

4.9.2 Identification marks are to be made on the outside of the straight part of the link, opposite the flash butt weld.

4.10 Certification

4.10.1 Certificates are to be issued in accordance with 3.9.

4.11 Documentation

4.11.1 Documentation in accordance with 3.10 is to be provided by the manufacturer.

■ *Section 5* **Short link chain cables**

5.1 Scope

5.1.1 This Section gives the requirements for electrically welded steel short link chain cable for marine use but excluding those applications covered by the *Code for Lifting Appliances in a Marine Environment*.

5.1.2 Provision is made for two grades, L(3) and M(4), as defined in ISO 1834. Allowance is also made for the requirements of ISO 4565.

5.2 Manufacture

5.2.1 Short link chain cables are to be manufactured at works approved by LR. A list of approved manufacturers for short link chain cable is published separately by LR.

5.2.2 The chain is to be supplied in either the normalized or quenched and tempered condition. Heat treatment is to be carried out prior to proof and breaking load testing.

5.2.3 The chain may be galvanized using a hot dipping process provided that this is carried out prior to proof and breaking load testing. If galvanized, it is recommended that the thickness of the zinc coating be not less than 70 microns.

5.2.4 Unless otherwise agreed, the finished chain is to be free from coatings other than zinc.

5.3 Bar material

5.3.1 Bars for the manufacture of short link chain cable are to be made and tested in accordance with the appropriate requirements of Ch 3,1 and to the requirements of an International or acceptable National Standard.

5.3.2 The bars are to be made at a works approved by LR.

5.3.3 The steel is to be fully killed and fine grain treated.

5.3.4 The steel is to have mechanical properties which will allow the chain to meet the mechanical test requirements of 5.4.7 and Table 10.5.1.

5.4 Testing and inspection of chain cables

5.4.1 All chain cable of 12,5 mm diameter and above, and all steering chains irrespective of diameter, are to be tested at a proving establishment recognized by LR. A list of recognized proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention is to be given to any relevant statutory requirements of the National Authority of the country in which the ship or other marine structure is to be registered.

5.4.2 For chain of diameter less than 12,5 mm, other than steering chains, the manufacturer's tests will be acceptable.

Table 10.5.1 Mechanical test requirements for short link chain cables

Chain diameter mm	Grade L(3) Proof load kN	Grade L(3) Breaking load minimum kN	Grade M(4) Proof load kN	Grade M(4) Breaking load minimum kN
5	—	—	7,9	15,8
6	9	18	—	—
6,3	—	—	12,5	25
7,1	—	—	15,9	31,8
8	16	32	20,2	40,4
9	—	—	25,5	51
10	25	50	31,5	63
11,2	—	—	39,5	79
12	35,5	71	—	—
12,5	—	—	49,1	98,2
14	—	—	63	126
16	—	—	81	162
18	—	—	102	204
20	—	—	126	252
22,4	—	—	158	316
25	—	—	197	394
28	—	—	247	494
32	—	—	322	644
36	—	—	408	816
40	—	—	503	1006
45	—	—	637	1274

5.4.3 After completion of all manufacturing processes, including heat treatment and galvanizing, the whole of the chain is to be subjected to the appropriate proof load specified in Table 10.5.1.

5.4.4 The whole of the chain is to be inspected after the proof load test and is to be free from significant defects.

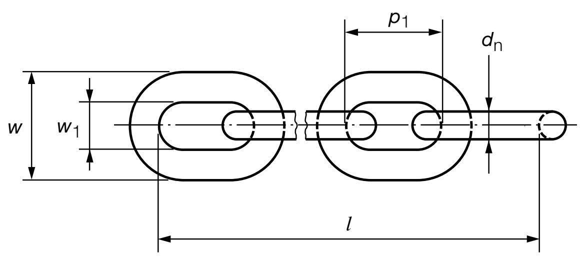
5.4.5 At least one sample, consisting of seven or more links, is to be selected by the Surveyor from each 200 m or less of chain for breaking load tests. Two additional links may be required for engagement in the jaws of the testing machine. These extra links are not to be taken into account in determining the total elongation, *see* 5.4.7.

5.4.6 The breaking load is to comply with the appropriate requirements of Table 10.5.1.

5.4.7 The total elongation of the breaking load sample at fracture, expressed as a percentage of the original inside length of the sample after proof loading, is to be not less than 20 per cent.

5.5 Dimensions and tolerances

5.5.1 The form and proportions of links are to be in accordance with Fig. 10.5.1.



d_n = nominal diameter of link
l = length over which dimensional tolerances are measured = $11p_1$
p_1 = pitch of chain = $3\,d_n$
w = outside width = $3{,}6\,d_n$
w_1 = inside width = $1{,}35\,d_n$

Fig. 10.5.1 Form and proportions of links

5.5.2 Manufacturing tolerances are to be within the following limits:

Nominal diameter, d_n	± 5%
Pitch of chain, p_1	± 3%
Length measured over 11 links, l	± 2%
Inside width, w_1	$1{,}35d_n$ minimum
Outside width, w	$3{,}6d_n$ maximum

The tolerances are to apply after galvanizing. All measurements are to be taken after proof testing.

5.6 Identification

5.6.1 All lengths of cable are to be stamped with the following identification marks:
(a) Inspector's mark and date.
(b) Reference mark or number of certificate.
(c) Manufacturer's mark or name.
(d) Chain cable quality mark.
Item (d), which shall be either L or M as appropriate, is to be stamped on at least each twentieth link or at intervals of one metre, whichever is the lesser distance.

5.6.2 Where the inspection is performed under LR's supervision, the inspector's mark and date are to be replaced by LR and the abbreviated name of LR's local office issuing the certificate.

5.7 Certification

5.7.1 The manufacturer is to supply the Surveyor with a certificate stating compliance with an appropriate ISO standard, and also, in the event of the requirements of 5.4 being undertaken other than in the presence of the Surveyor, stating that the test and inspection requirements have been complied with at a recognized proving establishment.

5.7.2 The certificate is also to include:
(a) the quality and description of chain,
(b) identification mark,
(c) nominal size of chain,
(d) proof load,
(e) breaking load,
(f) total elongation at fracture,
(g) where appropriate, the name of the proving establishment.

■ *Section 6* Steel wire ropes

6.1 Scope

6.1.1 Provision is made in this Section for the requirements for the manufacture, testing and certification of steel wire ropes intended to be used for general marine purposes, as well as permanent anchoring, mooring and marine lifting applications.

6.2 General requirements

6.2.1 For general marine purposes, such as stream wires, towlines and ship mooring lines, the construction is to be in accordance with Table 10.6.1. The construction, diameter and strength of steel wire ropes for permanent offshore applications, such as mooring, anchoring and lifting, are covered by other LR Rules. Alternative applications of wire ropes may be accepted, subject to special consideration.

6.2.2 The manufacturer's plant and method of production are to be approved by LR. A list of approved manufacturers of steel wire ropes is published annually in the *List of Approved Manufacturers of Materials*.

6.2.3 For shaped wire, for example, for large diameter ropes for permanent mooring, where there are no established Standards, the manufacturer is to provide evidence by way of test reports that specifications have been developed and agreed with the purchaser and LR for the purposes intended.

6.3 Steel wire for ropes

6.3.1 Steel wire is to be of homogeneous quality, uniform strength and free of defects likely to impair the manufacture and performance of the rope.

6.3.2 For all ropes, the specified minimum tensile strength of the wire is to be 1420, 1570, 1770 or 1960 N/mm^2. The specified minimum tensile strength of the wire is the designated grade for the rope, unless otherwise defined by the purchaser's specification. The actual tensile strength of the wire is not to exceed 120 per cent of the specified minimum tensile strength.

6.3.3 For new rope construction, the manufacturer is to carry out prototype testing suitable for the application of the rope and this is to include tests on wire used for the construction.

6.3.4 Tensile and torsion tests, coating, and adhesion (wrap) tests are to be carried out on wire used for the manufacture of rope.

6.3.5 At least 10 per cent of the spools used for the manufacture of the strand are to be tested. The manufacturer is to demonstrate that tests have been carried out on at least one wire intended for each of the outer and inner strands, and for each diameter and grade used.

6.3.6 The heat number, wire diameter and strength of wire used for a particular construction are to be recorded by the manufacturer.

6.3.7 Torsion tests are to be carried out on the wire by causing one or both of the securing vices to be revolved until fracture occurs (a tensile load not exceeding two per cent of the breaking load of the wire may be applied to keep the wire stretched).

6.3.8 The uncoated wire is to withstand, without fracture, the number of complete twists given for Grades 1 or 3 in Table 10.6.2.

6.3.9 The galvanized wire is to withstand, without fracture, the number of complete twists given in the specification, as agreed with the purchaser and LR. In the absence of a suitable specification, the results are to comply with Table 10.6.2.

Table 10.6.1 Recommended rope construction

Purpose	Construction of rope			Construction of strands
	Strands	Wires	Core	
Stream wires, towlines and mooring lines	6	24	Fibre	15 over 9 over fibre core
	6	37	Fibre	18 over 12 over 6 over 1
	6	26	Fibre	10 over (5 + 5) over 5 over 1
	6	31	Fibre	12 over (6 + 6) over 6 over 1
	6	36	Fibre	14 over (7 + 7) over 7 over 1
	6	41	Fibre	16 over (8 + 8) over 8 over 1
	6	30	Fibre	18 over 12 over fibre core
Towlines and mooring lines used in association with mooring winches	6	31	7 x 7 wire rope	12 over (6 + 6) over 6 over 1
	6	36	7 x 7 wire rope	14 over (7 + 7) over 7 over 1
	6	41	7 x 7 wire rope	16 over (8 + 8) over 8 over 1

Table 10.6.2 Torsion test

Diameter coated wire mm	Minimum number of twists					
	Grade 2		Grade 1 or 3			
	Minimum strength N/mm^2		Minimum strength N/mm^2			
	1570	1770	1420	1570	1770	1960
<1,3	19	18	29	26	23	23
≥1,3 <2,3	18	17	26	24	21	21
≥2,3 <3,0	16	14	24	22	—	19
≥3,0 <4,0	12	10	20	18	—	17
≥4,0 <4,6	—	—	18	16	—	—
≥4,6 <5,0	—	—	16	14	—	—
≥5,0 <6,0	—	—	14	11	—	—

NOTE
The minimum test length is 100*d* or 300 mm, where *d* is the wire diameter.

6.3.10 Hot dipped galvanized steel wire is to be used for the manufacture of ropes for marine applications. Depending upon the application, the coating may comply with any of the grades in Table 10.6.3. Grades 1 and 2 are heavy coatings. Grade 3 is the minimum coating weight where the galvanizing is carried out prior to final wire drawing. Uncoated wire may be considered for approved applications.

Table 10.6.3 Zinc coating

Diameter of coated wire mm	Zinc coating, minimum g/m^2		
	Grade1	Grade 2	Grade 3
≥0,20 <0,25	—	30	20
≥0,25 <0,33	—	45	30
≥0,33 <0,40	—	60	30
≥0,40 <0,50	60	75	40
≥0,50 <0,60	70	90	50
≥0,60 <0,80	85	110	60
≥0,80 <1,00	95	130	70
≥1,00 <1,20	110	150	80
≥1,20 <1,50	120	165	90
≥1,50 <1,90	130	180	100
≥1,90 <2,50	—	205	110
≥2,50 <3,20	—	230	125
≥3,20 <4,00	—	250	135

6.3.11 The mass per unit area of the zinc coating is to be determined in accordance with a recognized National or International Standard.

6.3.12 Zinc coating tests are to be carried out for each designated grade of wire. The manufacturer is to demonstrate that the coatings are continuous and uniform and suitable for the intended purpose.

6.3.13 Unless otherwise specified by the purchaser, zinc coating tests are to be carried out on the wire prior to stranding.

6.3.14 The adhesion of the coating is to be tested by wrapping the wire round a cylindrical mandrel for 10 complete turns. The ratio between the diameter of the mandrel and that of the wire is to be as in Table 10.6.4. After wrapping on the appropriate mandrel, the zinc coating is to have neither flaked nor cracked to such an extent that any zinc can be removed by rubbing with a cloth.

Table 10.6.4 Wrap test for adhesion of coating

Coating	Diameter of coated wire mm	Maximum ratio of mandrel to wire diameter
Grade 1 and 2	<1,5	4
	≥1,5	6
Grade 3	<1,5	2
	≥1,5	3

6.4 Tests on completed ropes

6.4.1 Every length of wire rope is to be subjected to a breaking strength test.

6.4.2 A sample of sufficient length is to be provided for the breaking load test. The rope ends are to be enclosed in a suitable socket. Testing is to be carried out in accordance with a recognized National or International Standard.

6.4.3 The rope may be subject to cyclic loading for bedding purposes prior to testing. The rope is to be tested at a suitable strain rate in accordance with a recognized National or International Standard.

6.4.4 The load is to be applied until one wire break is witnessed or 130 per cent of the minimum breaking load is recorded. The maximum recorded load is to be reported by the manufacturer.

6.4.5 Tests in which a breakage occurs adjacent to and as a result of damage from the grips are to be rejected, if the applied load is less than the specified minimum requirement. The rope is to be retested to withstand the agreed minimum breaking load.

6.4.6 With the exception of offshore mooring ropes, consideration may be given to determining the breaking load by summation or aggregating actual test results on individual wires, if facilities are not available for undertaking a breaking test on a production basis. A suitable spin factor or lay-up deduction allowance in accordance with a recognized National or International Standard for the applicable rope diameter, designated grade and construction is to be applied.

6.4.7 Where spin factors or lay-up deduction allowances are proposed by the manufacturer, a report on suitable cyclic load testing of prototype ropes of the same construction, strength and diameter is to be approved by LR. In addition, the manufacturer is to show that a satisfactory breaking load test has been carried out in the previous two years, and witnessed by LR for the same rope construction, diameter and designated grade.

6.4.8 LR may give special consideration to spin factors or lay deductions based on data extrapolated from smaller diameter ropes of the same construction, provided that these ropes have been tested in accordance with 6.4.7.

6.4.9 All data arising from smaller diameter ropes for the extrapolation in 6.4.8 are to have been derived from tests carried out within two years of the manufacture of the larger diameter rope.

6.4.10 The finished rope is to have no more than one wire connecting weld in any length of 18*d*, where *d* is the diameter of the rope.

6.5 Inspection

6.5.1 A report on dimensional and visual examination is to be presented to the Surveyor by the manufacturer. The dimensions and discard criteria are to comply with an agreed National or International Standard.

6.5.2 Visual and dimensional checks are to be carried out in the presence of the Surveyor.

6.6 Identification

6.6.1 All completed ropes are to be identified with attached labels detailing the rope type, diameter and length.

6.7 Certification

6.7.1 The manufacturer's certificate may be accepted. The certificate is to be validated by the manufacturer's representative, who is to be independent of the production process and LR.

6.7.2 Each test certificate is to contain the following particulars:
- Purchaser's name and order number.
- Details of the rope construction.
- Core material.
- Grade of zinc coating.
- Mechanical test results.
- Adhesion test results.
- Dimensions.
- Method of breaking load testing.
- Breaking load.

■ *Section 7* Fibre ropes

7.1 Manufacture

7.1.1 Fibre ropes intended as mooring lines may be made of coir, hemp, manila or sisal, or may be composed of synthetic (man-made) fibres. They may be three-strand (hawser laid), four-strand (shroud laid) or nine-strand (cable laid), but other constructions will be specially considered.

7.1.2 Each length of rope is to be manufactured from suitable material of good and consistent quality. Rope materials should, in general, comply with a recognized National Standard.

7.1.3 Synthetic fibre ropes are to be suitable for the purpose intended and should comply with a recognized standard.

7.1.4 Weighting and loading matter is not to be added, and any lubricant is to be kept to a minimum. Any rot-proofing or water repellancy treatment is not to be deleterious to the fibre nor is it to add to the weight or reduce the strength of the rope.

7.2 Tests of completed ropes

7.2.1 The breaking load is to be determined by testing to destruction a sample cut from the completed rope.

7.2.2 The minimum test length and the initial test load are to be as given in Table 10.7.1. After application of the initial load, the diameter and evenness of lay up of the sample are to be checked. The sample is then to be uniformly strained at the rate given in Table 10.7.1 until it breaks.

Table 10.7.1 Breaking load test

Material	Test length mm minimum	Initial load % (*see* Note)	Rate of straining mm/min
Natural fibre	1800	2	150 ± 50
Synthetic fibre	900	1	100 max.
NOTE Percentage of specified minimum breaking load.			

7.2.3 The actual breaking load is to be not less than that given in an appropriate National Standard.

7.2.4 If the sample is held by grips and the break occurs within 150 mm of the grips, the test may be repeated, but not more than two tests may be made on any one coil.

7.2.5 Where difficulty is experienced in testing a sample of a completed synthetic fibre rope, LR will consider alternative methods of testing.

7.3 Identification

7.3.1 Each coil of rope is to be identified with an attached label detailing the material, construction, diameter and length.

7.4 Certification

7.4.1 Printed certificates issued by the manufacturer or a competent governmental, municipal or similar responsible body will be accepted. These certificates are to give the breaking load, test length and rate of straining.

Approval of Welding Consumables

Section

■ *Section 1* General

1.1 Scope

1.1.1 Provision is made in this Chapter for the approval by Lloyd's Register (hereinafter referred to as 'LR') of electrodes, wires, fluxes and other consumables intended for use in the welding of the following types of materials:

(a) Steel of various grades as represented by Grade A through to Grade FH69, *see* Sections 3 to 7.
(b) A wide range of low-temperature service steels, *see* Sections 3 to 7.
(c) Stainless steels including nitrogen strengthened grades and some of the duplex varieties, *see* Section 8.
(d) Aluminium alloys, *see* Section 9.

1.1.2 For this purpose, welding, consumables are categorised and subject to the special requirements of different Sections of this Chapter.

(a) Covered electrodes for manual welding and gravity welding.
(b) Combinations of wire and flux for automatic submerged-arc welding.
(c) Combinations of wire and gas for gas metal-arc welding and wires for self-shielding welding.
(d) Combinations for electro-slag and electro-gas welding.
(e) Combinations with temporary backing materials for one-side welding.
(f) Consumables for welding austenitic and duplex stainless steels.
(g) Combinations for welding aluminium.

1.2 Grading

1.2.1 Consumables for welding structural steels are graded into ten strength levels, and each of these is further subdivided into several levels in respect of notch toughness. The five basic levels of toughness are indicated by a number (1 to 5). Normal tensile strength is indicated by 'N'. Higher tensile strength is indicated by 'Y', and if the yield strength is higher than 375 N/mm^2 the Y is followed by a number (40 to 69), as shown in Table 11.1.1.

1.2.2 In addition to the grade, consumables are also allocated a suffix indicating the welding technique used. These are defined in the context of the following Sections of this Chapter.

1.2.3 Consumables for structural and low temperature service steels may be controlled low hydrogen and approved as such. Grade marking H15, H10 or H5 will be applied, as appropriate.

1.2.4 For joining higher strength steels, approval granted for 1Y consumables will be limited to maximum material thickness of 25 mm.

1.2.5 Test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grade.

1.2.6 Further details of grading are given in subsequent Sections of this Chapter.

1.3 Manufacture

1.3.1 The manufacturer's plant and method of production of welding consumables are to be such as to ensure reasonable uniformity in manufacture.

1.4 Approval procedures

1.4.1 Welding consumables will be approved subject to a satisfactory inspection of the works by the Surveyor for compliance with the test requirements detailed in subsequent Sections in this Chapter.

1.4.2 The test assemblies are to be prepared under the supervision of the Surveyor, and using samples selected by him. All tests are to be carried out in his presence.

1.4.3 For Charpy V-notch tests, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Sections in this Chapter. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value.

1.4.4 Where chemical analysis is required for approval, the results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

Table 11.1.1 Welding consumable grades appropriate to structural and low temperature service steel grades

Consumable grade	Suitable for steel grades (*see* Notes)			
1. Ship Grade Steels (Ch 3,2 and Ch 3,3)				
1N	A	***AH27S***	–	–
2N	B, D	***DH27S***	–	–
3N	E	***EH27S***	–	–
1Y	A	***AH27S***	***AH32***	***AH36***
2Y	B, D	***DH27S***	***DH32***	***DH36***
3Y	E	***EH27S***	***EH32***	***EH36***
4Y	–	***FH27S***	***FH32***	***FH36***
2Y40	***AH32***	***AH36***	***AH40***	–
2Y40	***DH32***	***DH36***	***DH40***	–
3Y40	***EH32***	***EH36***	***EH40***	–
4Y40	***FH32***	***FH36***	***FH40***	–
2. Higher and High Strength Steels (Ch 3,3 and Ch 3,10)				
3Y42	***AH36***	***AH40***	AH42	–
3Y42	***DH36***	***DH40***	DH42	–
4Y42	***EH36***	***EH40***	EH42	–
5Y42	***FH36***	***FH40***	FH42	–
3Y46	***AH40***	AH42	AH46	–
3Y46	***DH40***	DH42	DH46	–
4Y46	***EH40***	EH42	EH46	–
5Y46	***FH40***	FH42	FH46	–
3Y50	AH42	AH46	AH50	–
3Y50	DH42	DH46	DH50	–
4Y50	EH42	EH46	EH50	–
5Y50	FH42	FH46	FH50	–
3Y55	AH50	AH55	–	–
3Y55	DH50	DH55	–	–
4Y55	EH50	EH55	–	–
5Y55	FH50	FH55	–	–
3Y62	AH55	AH62	–	–
3Y62	DH55	DH62	–	–
4Y62	EH55	EH62	–	–
5Y62	FH55	FH62	–	–
3Y69	AH62	AH69	–	–
3Y69	DH62	DH69	–	–
4Y69	EH62	EH69	–	–
5Y69	FH62	FH69	–	–
3. Ferritic Low Temperature Service Steels (Ch 3,6)				
$1\frac{1}{2}$ Ni	$1\frac{1}{2}$ Ni	–	–	–
$3\frac{1}{2}$ Ni	$3\frac{1}{2}$ Ni	–	–	–
5 Ni	5 Ni	–	–	–
9 Ni	9 Ni	–	–	–

NOTES
1. Steel grades shown in bold italic type include the equivalent (LT-xxxx) low temperature service grades referenced in Ch 3,6.
2. The Table applies to the multi-run welding techniques (i.e. m, S, M).

1.4.5 LR may require, in any particular case, such additional tests or requirements as may be necessary.

1.4.6 A *List of Approved Welding Consumables* is published by LR.

1.4.7 LR is to be notified of any alteration proposed to be made in the process of manufacture subsequent to approval. Sufficient detail is to be provided to determine the need for further testing to maintain the approval.

1.4.8 Consideration will be given to alternative procedures for approval in the case of manufacturers producing consumables under the control of another manufacturer or plant already having approval of one or more products.

1.5 Annual inspection and tests

1.5.1 All establishments where approved welding consumables are manufactured, and the associated quality control procedures, are to be subjected to annual inspection. On these occasions, samples of the approved consumables are to be selected by the Surveyor and subjected to the tests detailed in subsequent Sections in this Chapter. These are to be completed and reported before the end of the one year period beginning at the initial approval date, and repeated annually so as to provide at least an average of one annual test per year.

1.6 Changes in grading

1.6.1 Changes in grading of welding consumables will be considered only at the manufacturer's request, preferably at the time of annual testing. For upgrading and uprating, tests from butt weld assemblies will be required in addition to the normal annual approval tests. Downgrading and downrating may be imposed by LR where tests and re-tests fail to meet the requirements of this Chapter.

1.7 Manufacturers' Quality Assurance Systems

1.7.1 As an alternative to 1.5, manufacturers may seek maintenance of approval based on acceptance by LR of their 'in house' quality assurance system, and by regular audit of that system carried out in accordance with procedures approved by LR.

■ *Section 2*
Mechanical testing procedures

2.1 Dimensions of test specimens

2.1.1 Deposited metal tensile test specimens are to be machined to the dimensions shown in Fig. 11.2.1, and may be heated to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal, prior to testing.

2.1.2 Butt weld tensile test specimens are to be machined to the dimensions shown in Fig. 11.2.2. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

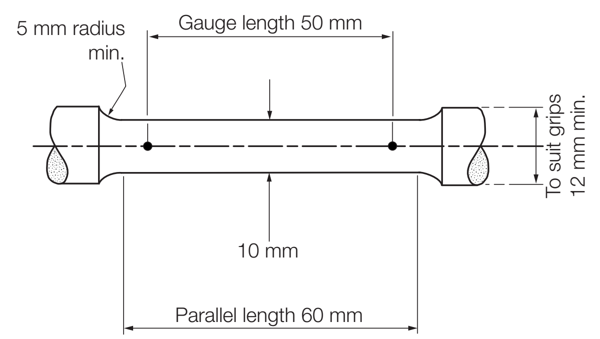


Fig. 11.2.1
Deposited metal tensile test specimen

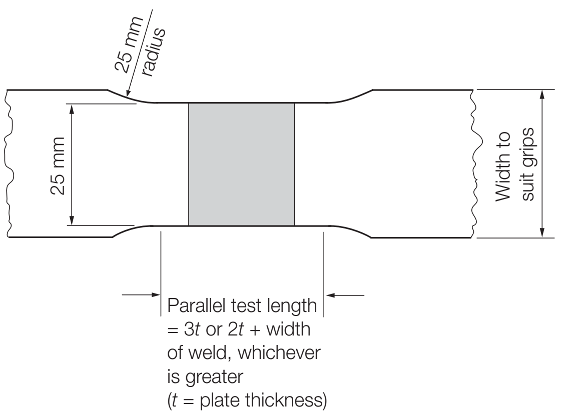


Fig. 11.2.2 Butt weld tensile test specimen

2.1.3 Butt weld face and root bend test specimens are to be 30 mm in width and of the full plate thickness. Where the thickness exceeds 25 mm, two side bend test specimens may be tested in place of the face and root specimens specified. The side bend specimens should be 10 mm minimum thickness. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate. The edges on the tension side are to be rounded to a radius of 1 to 2 mm. The highest convenient rate of bending (but not impact) should be used.

2.1.4 All impact test specimens are to be of the standard 10 mm x 10 mm Charpy V-notch type, machined to the dimensions and tolerances detailed in Ch 2,3.

2.2 Testing procedures

2.2.1 The procedures used for all tensile and impact tests are to comply with the requirements of Chapter 2.

2.2.2 Butt weld bend test specimens are to be tested at ambient temperature and are to be bent through an angle of 120° over a former having a diameter which relates to the thickness of the test specimen as detailed in subsequent Sections. For each pair of bend test specimens, one specimen is to be tested with the face of the weld in tension and the other with the root of the weld in tension.

2.2.3 Macro examinations are to be carried out on polished and etched specimens at a maximum magnification not exceeding x10. The examination is to ensure complete fusion, inter-run penetration and freedom of defects.

2.3 Re-test procedures

2.3.1 Where the result of a tensile or bend test does not comply with the requirements, duplicate test specimens of the same type are to be prepared and satisfactorily tested. Where insufficient original welded assembly is available, a new assembly is to be prepared using welding consumables from the same batch. If the new assembly is made with the same procedure (particularly the same number of runs) as the original assembly, only the duplicate re-test specimens need be prepared and tested. Otherwise, all test specimens are to be prepared and tested as for the original assembly.

2.3.2 Where the results from a set of three impact test specimens do not comply with the requirements, an additional set of three impact test specimens may be taken provided that not more than two individual values are less than the required average value and, of these, not more than one is less than 70 per cent of this average value. The results obtained are to be combined with the original results to form a new average (of six) which, for acceptance, is to be not less than the required average value. Additionally, for these combined results, not more than two individual values are to be less than the required average value and, of these, not more than one is to be less than 70 per cent of the average value. Further re-tests may be made at the Surveyor's discretion, in accordance with 2.3.1.

■ *Section 3*
Electrodes for manual and gravity welding

3.1 General

3.1.1 Dependent on the results of the mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

3.1.2 Approval of an electrode will be given in conjunction with a welding technique indicated by a suffix 'm' for manual welding, 'G' for gravity or contact electrode and 'p' for deep penetration electrode.

3.1.3 If the electrodes are in compliance with the requirements of the hydrogen test given in 3.4, a suffix 'H15' or 'H10' or 'H5' will be added to the grade mark. Table 11.3.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

Table 11.3.1 Minimum low hydrogen approval requirements for manual and gravity electrodes

Approval grades	Low hydrogen grade required
1 (1N), 2 (2N), 3 (3N)	NR
2Y, 3Y, 4Y	H15 (*see* Note 2)
2Y40 to 4Y40	H15
3Y42 to 5Y42	H10
3Y46 to 5Y46	H10
3Y50 to 5Y50	H10
3Y55 to 5Y55	H5
3Y62 to 5Y62	H5
3Y69 to 5Y69	H5
$1^1/2$ Ni	H15
$3^1/2$ Ni	H15
5 Ni	NR (*see* Note 3)
9 Ni	NR (*see* Note 3)

NOTES
1. NR – Not required, but approval can be sought, if desired.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

3.1.4 For each strength level, electrodes which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower grade.

3.1.5 Electrodes approved for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

3.1.6 Electrodes approved for strength levels between Y40 and up to and including Y50 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

3.1.7 Electrodes approved for strength levels Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

3.1.8 The welding current used is to be within the range recommended by the manufacturer and, where an electrode is stated to be suitable for both a.c. and d.c., a.c. is to be used for the preparation of the test assemblies.

3.1.9 Where an electrode is submitted only for approval for fillet welding and to which the butt weld test provided in 3.3 is not considered applicable, approval tests are to consist of the fillet weld tests as given in 3.5 and deposited metal tests with chemical analyses as given in 3.2.

3.1.10 Where an electrode is submitted for approval of both butt and fillet welding, approval tests are to include the deposited metal tests as given in 3.2, the butt weld tests as given in 3.3, and only one fillet weld test as given in 3.5 welded in the horizontal-vertical position.

3.2 Deposited metal test assemblies

3.2.1 The deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one with 4 mm diameter electrodes and the other with 8 mm diameter electrodes, or the largest size manufactured if this is less than 8 mm diameter. If an electrode is available in one diameter only, one test assembly is sufficient. Any of the grades of steel in Table 11.1.1 may be used for the preparation of these assemblies, up to a strength level which is not more than two levels above that for which approval is sought.

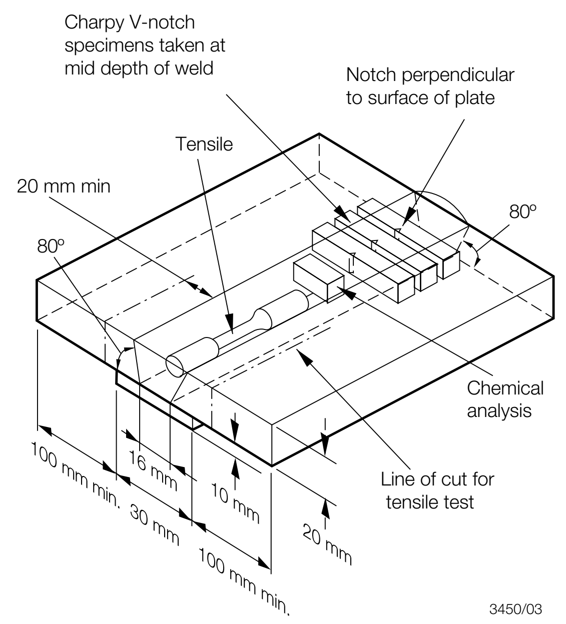


Fig. 11.3.1 Deposited metal test assembly

3.2.2 The weld metal is to be deposited in single- or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm and not more than 4 mm thick. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grading.

3.2.3 The chemical analysis of the deposited weld metal in each deposited metal test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

3.2.4 One tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.3.1. Care is to be taken that the axis of the tensile test specimen coincides with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld, with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

3.2.5 The results of all tests are to comply with the requirements of Table 11.3.2 as appropriate.

3.3 Butt weld test assemblies

3.3.1 Butt weld assemblies, as shown in Fig. 11.3.2, are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the electrode is recommended by the manufacturer. In the case of electrodes for normal strength and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), electrodes satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. In all other cases, approval for the horizontal-vertical position will require a butt weld to be made in that position and fully tested.

Table 11.3.2 Requirements for deposited metal tests (covered electrodes)

Grade (*see* Note 3)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2 (*see* Note 1)	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note 2) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	47
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	47
2Y40	400	510 – 690	22	0	47
3Y40	400	510 – 690	22	–20	47
3Y42	420	530 - 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	47
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
$1^1/2$ Ni	375	460	22	–80	34
$3^1/2$ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTES
1. Single values are the minimum requirements.
2. Energy values from individual impact test specimens are to comply with 1.4.3.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

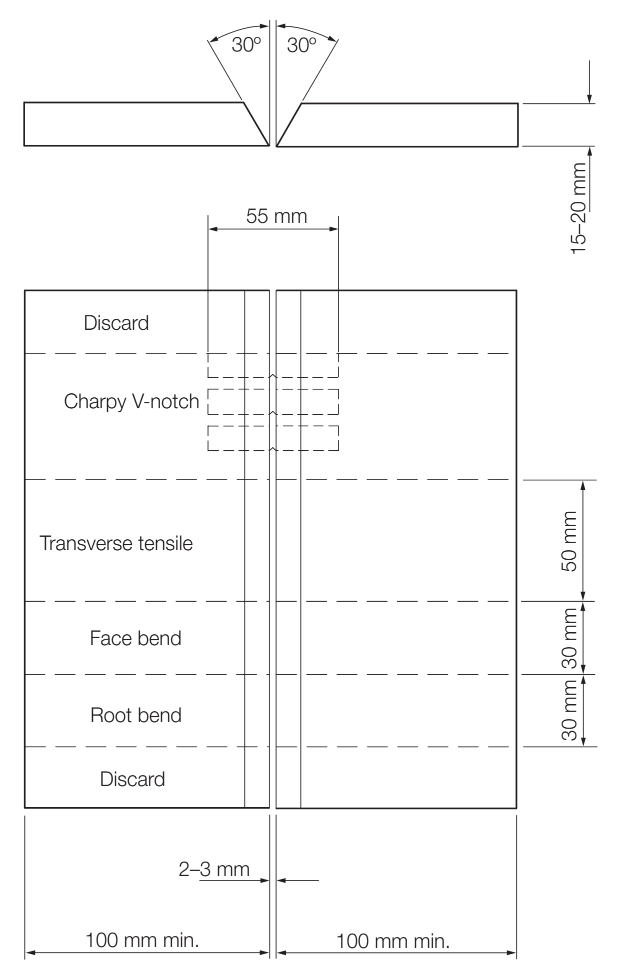


Fig. 11.3.2 Butt weld test assembly

3.3.2 Where the electrode is to be approved only in the downhand position, an additional test assembly is to be prepared in that position.

3.3.3 The grades of steel used for the preparation of the test assemblies are to be as follows:

Grade 1 (1N) electrodes	A
Grade 2 (2N) electrodes	A, B or D
Grade 3 (3N) electrodes	A, B, D or E
Grade 2Y electrodes	AH32, AH36, DH32 or DH36
Grade 3Y electrodes	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y electrodes	AH32 AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 electrodes	AH40 or DH40
Grade 3Y40 electrodes	AH40, DH40 or EH40
Grade 4Y40 electrodes	AH40, DH40, EH40 or FH40

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

3.3.4 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

3.3.5 The test assemblies are to be made by welding together two plates of equal thickness (15 to 20 mm), not less than 100 mm in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size. The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root gap 2 to 3 mm. The root face is to be 0 to 2 mm.

3.3.6 The following welding procedure is to be adopted in making the test assemblies:

Downhand (a). The first run with 4 mm diameter electrode. Remaining runs (except the last two layers) with 5 mm diameter electrodes or above according to the normal welding practice with the electrodes. The runs of the last two layers with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Dowhand (b) (where a second downhand test is required). First run with 4 mm diameter electrode. Next run with an electrode of intermediate diameter of 5 mm or 6 mm, and the remaining runs with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Horizontal-vertical. First run with 4 mm or 5 mm diameter electrode. Subsequent runs with 5 mm diameter electrodes.

Vertical-upward and overhead. First run with 3,25 mm diameter electrode. Remaining runs with 4 mm diameter electrodes or possibly with 5 mm if this is recommended by the manufacturer for the positions concerned.

Vertical-downward. If the electrode being tested is intended for vertical welding in the downward direction, this technique is to be adopted for the preparation of the test assembly using electrode diameters as recommended by the manufacturer.

3.3.7 For all assemblies, the back sealing runs are to be made with 4 mm diameter electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

3.3.8 Normal welding practice is to be used and, between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code ‘sr’ will be added to the approval grading.

Table 11.3.3 Requirements for butt weld tests (covered electrodes)

Grade (*see* Note 3)	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Note 1) J minimum All positions (*see* Note 2)
1N, 2N, 3N	400	3	+20, 0, –20	47 (34)
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	47 (34)
2Y40	510	3	0	47 (39)
3Y40	510	3	–20	47 (39)
3Y42	530 – 680	4	–20	47
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	47 (39)
4Y42	530 – 680	4	–40	47
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y42	530 – 680	4	–60	47
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
$1^1/_2$ Ni	490	3	–80	27
$3^1/_2$ Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Values in ( ) apply only to welds made in the vertical position with upward progression.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

3.3.9 It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

3.3.10 The test specimens as shown in Figs. 11.3.2 and 11.3.3 are to be prepared from each test assembly.

3.3.11 The results of all tensile and impact tests are to comply with the requirements of Table 11.3.3 as appropriate. The position of fracture in the transverse tensile test is to be reported.

3.3.12 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defect exceeding 3 mm in dimensions can be seen on the outer surface.

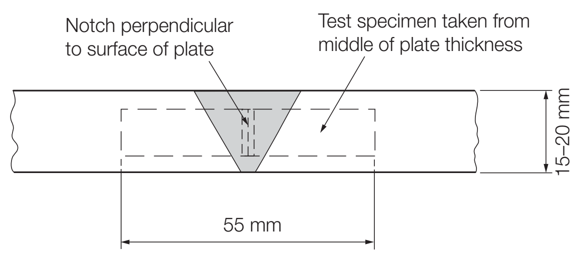


Fig. 11.3.3
Butt weld test assembly position of impact test specimens

3.4 Hydrogen test

3.4.1 The hydrogen gradings are specified in 3.1.3. The hydrogen grading required determines the method of testing permitted as shown in Table 11.3.4.

Table 11.3.4 Permitted methods for obtaining low hydrogen grading

Hydrogen Grade	Permitted Method
H15	ISO 3690 (or Glycerine) (*See* Note)
H10	ISO 3690
H5	ISO 3690
NOTE ISO method preferred.	

3.5 Fillet weld test assemblies

3.5.1 Fillet weld assemblies as shown in Fig. 11.3.4 are to be prepared for each welding position (horizontal-vertical, vertical-upward, vertical-downward or overhead) for which the electrode is recommended by the manufacturer. The grade of steel used for the test assemblies is to be as detailed in 3.3.3. The length of the test assembly, *L*, is to be sufficient to allow at least the deposition of the entire length of the largest diameter electrode being tested.

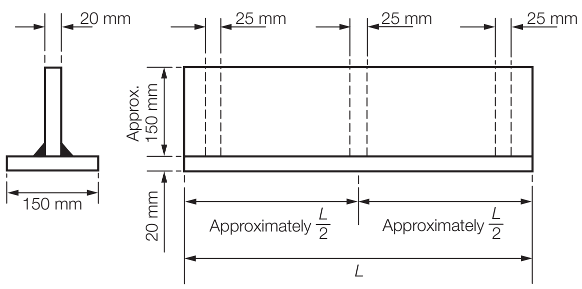


Fig. 11.3.4 Fillet weld test assembly

3.5.2 The electrode sizes to be used are the maximum and minimum diameters recommended by the manufacturer for fillet welding. The first side is to be welded using the maximum diameter. The second side is to be welded only after the assembly has been allowed to cool below 50°C using the minimum diameter. The size of these single run fillet welds will, in general, be determined by the electrode size and the welding current employed during testing and should represent the range of fillet weld bead sizes recommended by the manufacturer.

3.5.3 Each test assembly is to be sectioned to form three macro-sections, each about 25 mm thick. These are to be examined for root penetration, satisfactory profile, freedom from cracking and reasonable freedom from porosity and slag inclusions. Any undercut is not to exceed 0,5 mm in depth. Convexity or concavity of the profile is not to exceed one-tenth of the fillet bead throat dimension. All such observations are to be reported.

3.5.4 Hardness measurements are to be made on the central macro-section only, as shown in Fig. 11.3.5. The results are to be reported.

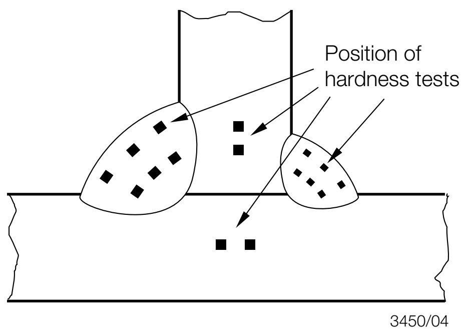


Fig. 11.3.5
Hardness tests for fillet weld test assembly

3.5.5 One of the remaining sections of the assembly is to have the weld on the first side gouged or machined to facilitate breaking the fillet weld on the second side by closing the two plates together, subjecting the root of the weld to tension. On the other remaining section, the weld on the second side is to be gouged or machined and the section fractured using the same procedure. The fractured surfaces are to be examined. They are to show satisfactory penetration, freedom from cracks and reasonable freedom from porosity and this should be reported.

3.6 Electrodes designed for deep penetration welding

3.6.1 Where an electrode is designed solely for the deep penetration welding of downhand butt joints and horizontal-vertical fillets in normal tensile strength steel, only the tests detailed in 3.7 and 3.8 are required for approval purposes.

3.6.2 Electrodes designed solely for the deep penetration welding technique will be approved as complying with Grade 1 requirements only and will be given the suffix ‘p’.

3.6.3 Where a manufacturer recommends that an electrode having deep penetrating properties can also be used for downhand butt welding of thicker plates with prepared edges, the electrode will be treated as a normal penetration electrode, and the full series of tests in the downhand position is to be carried out, together with the deep penetration tests given in 3.7 and 3.8.

3.6.4 Where a manufacturer desires to demonstrate that an electrode, in addition to its use as a normal penetration electrode, also has deep penetrating properties when used for downhand butt welding and horizontal fillet welding, the additional tests given in 3.7 and 3.8 are to be carried out.

3.6.5 Electrodes approved for both normal and deep penetration welding will have the suffix p added after the appropriate grade mark for normal penetration welding.

3.6.6 Where the manufacturer prescribes a different welding current and procedure for the electrode when used as a deep penetration electrode and a normal penetration electrode, the recommended current and procedure are to be used when making the test assemblies in each case.

3.7 Deep penetration butt weld test assemblies

3.7.1 Two plates of thickness equal to twice the diameter of the core of the electrode plus 2 mm are to be butt welded together with one downhand run of welding from each side. The plates are to be not less than 100 mm wide and of sufficient length to allow the cutting out of the test specimens of the correct number and size as shown in Fig. 11.3.6. Grade A steel is to be used for these test assemblies. The joint edges are to be prepared square and smooth and, after tacking, the gap is not to exceed 0,25 mm. The test assembly is to be welded using an 8 mm diameter electrode, or the largest diameter manufactured if this is less than 8 mm and the assembly is to be allowed to cool below 50°C between runs.

3.7.2 The test specimens as shown in Figs. 11.3.3 and 11.3.6 are to be prepared from each test assembly.

3.7.3 The results of tensile and impact tests are to comply with the requirements of Table 11.3.3 for Grade 1 electrodes. The position of fracture in the tensile test is to be reported. The bend test specimens are to be in accordance with 3.3.12.

3.7.4 The discards at the end of the welded assemblies are to be not more than 35 mm wide. The joints of these discards are to be polished and etched and must show complete fusion and inter-penetration of the weld beads. At each cut in the test assembly, the joints are also to be examined to ensure that complete fusion has taken place.

3.8 Deep penetration fillet weld test assemblies

3.8.1 A fillet weld assembly is to be prepared as shown in Fig. 11.3.7 with plates about 12,5 mm in thickness. The welding is to be carried out with one run for each fillet with plate A in the horizontal plane during the welding operations. The length of the fillet is to be 160 mm and the gap between the plates is to be not more than 0,25 mm. Grade A steel is to be used for these test assemblies.

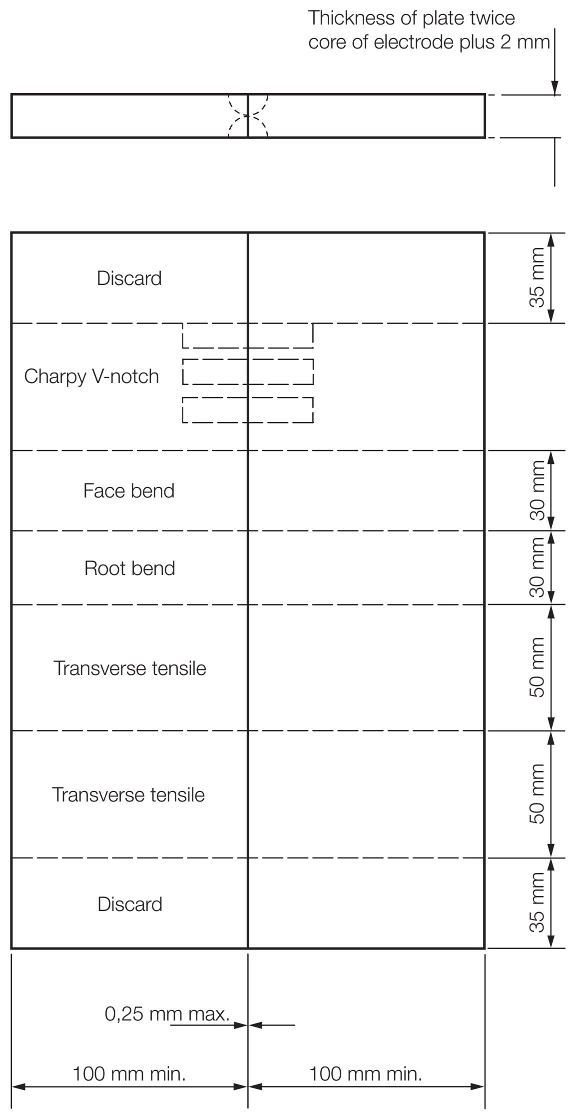


Fig. 11.3.6
Deep penetration butt weld test assembly

3.8.2 The fillet weld on one side of the assembly is to be carried out with a 4 mm diameter electrode, and that on the other side with the maximum diameter of electrode manufactured. The welding current used is to be within the range recommended by the manufacturer, and the welding is to be carried out using normal welding practice except that the assembly is to be allowed to cool below 50°C between runs.

3.8.3 The welded assembly is to be cut by sawing or machining within 35 mm of the ends of the fillet welds, and the joints are to be polished and etched. The welding of the fillet made with a 4 mm diameter electrode is to show a penetration of 4 mm (*see* Fig. 11.3.7) and the corresponding penetration of the fillet made with the maximum diameter of electrode manufactured is to be reported.

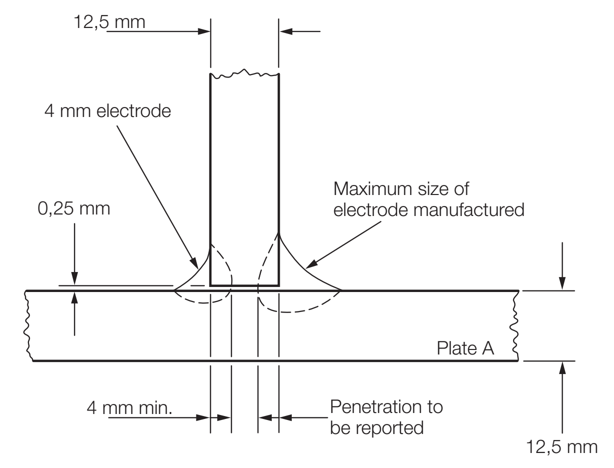


Fig. 11.3.7
Deep penetration fillet weld test assembly

3.9 Electrodes designed for gravity or contact welding

3.9.1 Approval for welding using the gravity, 'G', technique is available for welding only normal strength and higher tensile steels up to and including Grade 36.

3.9.2 Where an electrode is submitted solely for approval for use in contact welding using automatic gravity or similar welding devices, deposited metal tests, butt weld tests and, where appropriate, fillet weld tests similar to those for normal manual electrodes are to be carried out using the process for which the electrode is recommended by the manufacturer.

3.9.3 Where an electrode is submitted for approval for use in contact welding using automatic gravity or similar welding devices in addition to normal manual welding, butt weld and, where appropriate, fillet weld tests, using the gravity or other contact device as recommended by the manufacturer, are to be carried out in addition to the normal approval tests.

3.10 Certification

3.10.1 Each carton or package of approved electrodes is to contain a certificate from the manufacturer generally in accordance with the following:

> 'The............................company certifies that the composition and quality of these electrodes conform with those of the electrodes used in making the test pieces submitted to and approved by the approval bodies nominated on the label of this package.'

3.10.2 Additionally, the manufacturer will be required to sign a similar declaration relating to continuing production.

3.11 Annual tests

3.11.1 For normal penetration electrodes, the annual tests are to consist of two deposited metal test assemblies. These are to be prepared and tested in accordance with 3.2. If an electrode is available in one diameter only, one test assembly is sufficient.

3.11.2 Where an electrode is approved solely for deep penetration welding, the annual test is to consist of one butt welded test assembly. This is to be prepared and tested in accordance with 3.7.

3.11.3 Where an electrode is approved for both normal and deep penetration welding, annual tests as detailed in 3.11.1 and 3.11.2 are to be carried out.

3.11.4 Where an electrode is approved solely for gravity or contact welding, the annual test is to consist of one deposited metal test assembly using the gravity or other contact device as recommended by the manufacturer.

3.11.5 Where an electrode is approved for both manual and gravity welding, annual tests as detailed in 3.11.1 and 3.11.4 are to be carried out.

■ *Section 4*
Wire-flux combinations for submerged-arc automatic welding

4.1 General

4.1.1 Wire-flux combinations for single and multiple electrode submerged-arc automatic welding, without the use of temporary backing, are divided into the following two categories:

- For use with the multi-run technique.
- For use with the two-run technique.

Where particular wire-flux combinations are intended for welding with both techniques, tests are to be carried out for each technique.

4.1.2 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

4.1.3 The suffixes T or M will be added after the grade mark to indicate approval for the two-run technique or, multi-run technique respectively.

4.1.4 Wire-flux combinations satisfying the requirements for multi-run or two-run techniques will also be approved for fillet welding in the downhand and horizontal-vertical position, subject to agreement by the manufacturer.

4.1.5 If the consumable combination is in compliance with the requirements of the hydrogen test given in 3.4, a suffix H15, H10 or H5 will be added to the grade. Table 11.4.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

Table 11.4.1 Minimum low hydrogen approval requirements for wire-flux combinations

Approval grade	'H' grade for Multi-run	'H' grade for Two-run
1 (1N), 2 (2N), 3 (3N)	NR	NR
1Y, 2Y, 3Y, 4Y	NR	NR
2Y40 to 4Y40	H15	NR
3Y42 to 5Y42	H10	H15
3Y46 to 5Y46	H10	H15
3Y50 to 5Y50	H10	H10
3Y55 to 5Y55	H5	H10
3Y62 to 5Y62	H5	H5
3Y69 to 5Y69	H5	H5
1 1/2 Ni	H15	NR
3 1/2 Ni	H15	NR
5 Ni (*see* Note 2)	NR	NR
9 Ni (*see* Note 2)	NR	NR

NOTES
1. NR – Not required, but approval can be sought, if desired.
2. Assumes use of an austenitic, non-transformable, filler material.

4.1.6 For each strength level, wire-flux combinations which have satisfied the requirements for a higher grade are considered as complying with the requirements for a lower grade.

4.1.7 Wire-flux combinations approved with multi-run technique for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

4.1.8 Wire-flux combinations approved with multi-run technique for strength levels between Y40 and up to and including Y50 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

4.1.9 Wire-flux combinations approved with multi-run technique for strength levels Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

4.1.10 Wire-flux combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 4.5.1.

4.1.11 The welding current may be either a.c. or d.c. (electrode positive or negative) according to the recommendation of the manufacturer. If both a.c. and d.c. are recommended, a.c. is to be used for the tests.

4.1.12 Wire-flux combinations for multiple electrode submerged-arc welding will be subject to separate approval tests. These are to be carried out generally in accordance with the requirements of this Section.

4.1.13 Wire-flux combinations are not naturally low hydrogen in character, but for the lower strength grades of steel low hydrogen testing is not normally a requirement for approval. With higher strength steels it is more important and Table 11.4.1 shows the mandatory minimum low hydrogen status required for approval of wire-flux combinations.

4.2 Approval tests for multi-run technique

4.2.1 Where approval for use with the multi-run technique is requested, deposited metal and butt weld tests are to be carried out.

4.3 Deposited metal test assemblies (multi-run technique)

4.3.1 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1, using any of the grades of steel in Table 11.1.1 up to a strength level which is not more than two levels above that for which approval is sought.

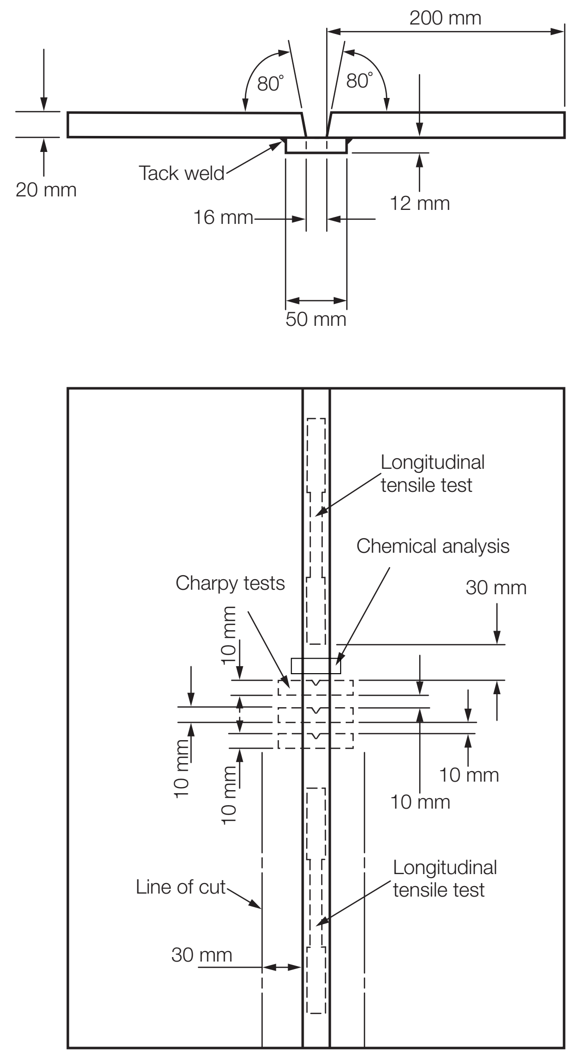


Fig. 11.4.1 Deposited metal test assembly

4.3.2 The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case any remaining scale is to be removed from the bevelled edges.

4.3.3 Welding is to be in the downhand position, and the direction of deposition of each run is to alternate from each end of the plate. After completion of each run, the flux and welding slag are to be removed. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. The thickness of the layer is to be not less than the diameter of the wire nor less than 4 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

4.3.4 The welding conditions (amperage, voltage and rate of travel) are to be in accordance with the recommendations of the manufacturer and are to conform with normal good welding practice for multi-run welding.

4.3.5 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

4.3.6 Two longitudinal tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.4.1. Care is to be taken that the axes of the tensile test specimens coincide with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

4.3.7 In those cases where two-run technique approval is also sought, only one longitudinal tensile specimen need be prepared and tested from this assembly.

4.3.8 The results of all tests are to comply with the requirements of Table 11.4.2, as appropriate.

4.4 Butt weld test assemblies (multi-run technique)

4.4.1 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2.

Table 11.4.2 Requirements for deposited metal tests (wire-flux combinations)

Grade	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	34
2Y40	400	510 – 690	22	0	39
3Y40	400	510 – 690	22	–20	39
3Y42	420	530 – 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	39
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
1½ Ni	375	460	22	–80	34
3½ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTE
Energy values from individual impact test specimens are to comply with 1.4.3.

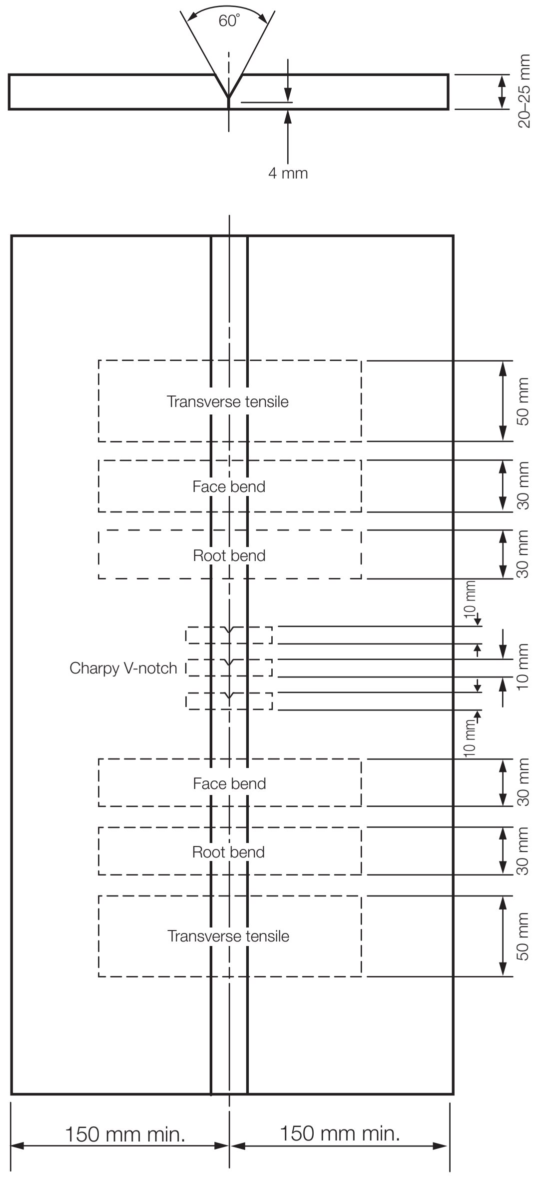


Fig. 11.4.2
Butt weld test assembly (multi-run technique)

4.4.2 The grade of steel used for the preparation of the test assembly are to be as follows:

Grade 1 wire-flux combination	A
Grade 2 wire-flux combinations	A, B or D
Grade 3 wire-flux combinations	A, B, D or E
Grade 1Y wire-flux combination	AH32 or AH36
Grade 2Y wire-flux combinations	AH32, AH36, DH32 or DH36
Grade 3Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 wire-flux combination	AH40 or DH40
Grade 3Y40 wire-flux combinations	AH40, DH40 or EH40
Grade 4Y40 wire-flux combinations	AH40, DH40, EH40 or FH40

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

4.4.3 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

4.4.4 The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root face being 4 mm. The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from bevelled edges.

4.4.5 Welding is to be carried out in the downhand position by the multi-run technique, and the welding conditions are to be the same as those adopted for the deposited metal test assembly. The back sealing run is to be applied in the downhand position after cutting out the root run to clean metal.

4.4.6 It is recommended that the welded assembly be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

4.4.7 The test specimens as shown in Fig. 11.3.3 and Fig. 11.4.2 are to be prepared from each test assembly.

4.4.8 The results of all tensile and impact tests are to comply with the requirements of Table 11.4.3, as appropriate. The position of fracture of the transverse tensile test is to be reported.

4.4.9 The bend test specimens can be considered as complying with the requirements if, after bending, no cracks or other open defects exceeding 3 mm in dimension can be seen on the outer surface.

4.5 Approval tests for two-run technique

4.5.1 Where approval for use with the two-run technique is requested, two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

4.5.2 Each pair of welded assemblies is to be made from plates of two thicknesses. The thickness of the thicker pair of plates will be the maximum for which the approval is valid. The second assembly is to be welded from plates having approximately half of the thickness of the first assembly.

Table 11.4.3 Requirements for butt weld tests (wire-flux combinations)

Grade	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Notes 1 and 2) J minimum
1N, 2N, 3N	400	3	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	34
2Y40	510	3	0	39
3Y40	510	3	–20	39
3Y42	530 – 680	4	–20	47 (41)
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	39
4Y42	530 – 680	4	–40	47 (41)
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y42	530 – 680	4	–60	47 (41)
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
$1^1/_2$ Ni	490	3	–80	27
$3^1/_2$ Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

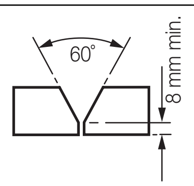
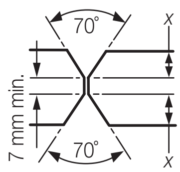
NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Values in ( ) apply only to two-run technique impact test specimens.

4.6 Butt weld test assemblies (two-run technique)

4.6.1 The grade of steel used for the preparation of the test assemblies is not to be of any higher grade (impact toughness) than that for which approval is required. The chemical composition, including the content of grain refining elements, and the strength properties of the plates used, are to be reported.

4.6.2 The maximum diameter of wire and the edge preparation to be used are to be in accordance with Table 11.4.4. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The bevelling of the plate edges is to be performed by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from the bevelled edges. The root gap should not exceed 0,7 mm.

Table 11.4.4 Butt weld assembly preparation

Plate thickness mm	Recommended diameter	Maximum diameter of wire mm
12,5		5
20–25		6
35–40		7

4.6.3 Each butt weld is to be welded in two runs, one from each side, using amperages, voltages and travel speeds in accordance with the recommendations of the manufacturer and normal good welding practice. After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to less than 100°C, the temperature being taken in the centre of the weld, on the surface of the seam.

4.6.4 It is recommended that the butt weld assemblies be subjected to radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

4.6.5 The test specimens, as shown in Fig. 11.4.3 and Fig. 11.4.4, are to be prepared from each test assembly. The edges of two of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. At each cut in the test assembly, the edges are also to be examined to ensure that complete fusion has taken place.

4.6.6 The results of transverse tensile and impact tests are to comply with the requirements of Table 11.4.3 as appropriate. The position of fracture of the transverse tensile tests is to be reported.

4.6.7 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defects exceeding 3 mm in dimensions can be seen on the outer surface. One of the specimens from each assembly is to be tested with the side first welded in tension, and the second specimen with the other side in tension.

4.6.8 The longitudinal tensile specimen shown in Fig. 11.4.3 is to be prepared from the thicker assembly, even in those cases where multi-run technique approval is also sought. This test specimen is to be machined to the dimensions shown in Fig. 11.2.1, and the longitudinal axis is to coincide with the centre of the weld about 7 mm below the plate surface on the side from which the second run is made. The test specimen may be given a hydrogen release treatment in accordance with 2.1.1. The results of this test are to comply with the requirements of Table 11.4.2.

4.6.9 The chemical analysis of the weld metal of the second run in each assembly is to be determined and reported. This is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

4.7 Annual tests

4.7.1 Annual tests are to consist of at least the following:

(a) For wire-flux combinations approved for the multi-run technique, one deposited metal test assembly.

(b) For wire-flux combinations approved for the two-run technique, one butt weld test assembly using plate material 20 to 25 mm in thickness.

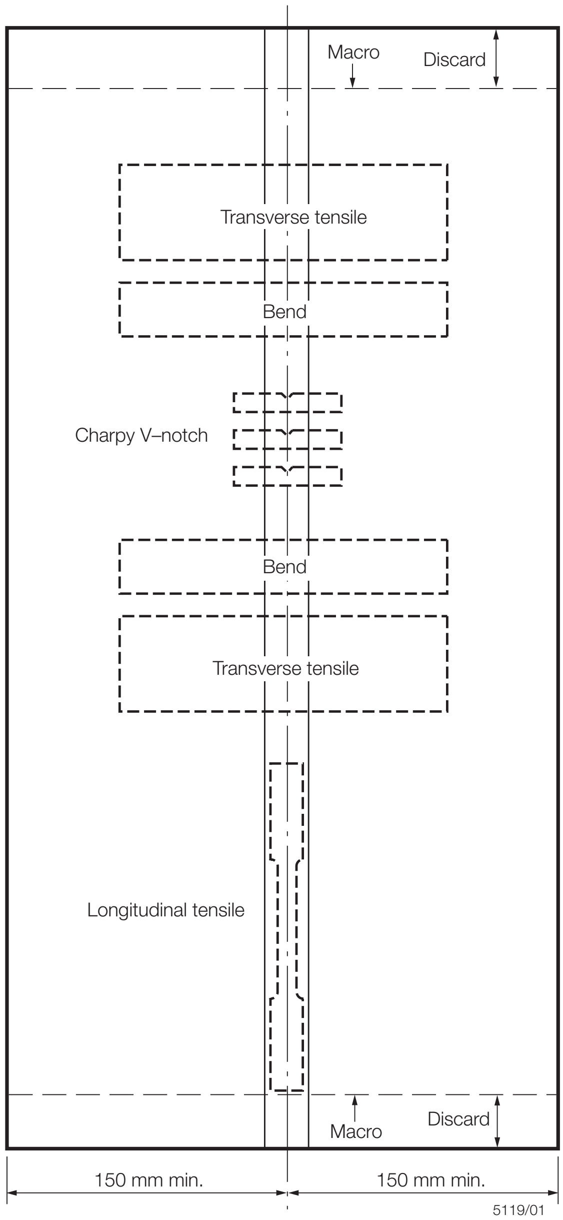


Fig. 11.4.3
Butt weld test assembly (two-run technique)

4.7.2 The deposited metal assemblies are to be prepared and tested in accordance with 4.3, except that only one longitudinal tensile, three impact test specimens and a chemical analysis are required.

4.7.3 The butt weld test assemblies are to be prepared and tested in accordance with 4.6, except that only one transverse tensile, two bend, three impact test specimens and a chemical analysis are required. One longitudinal tensile test specimen is also to be prepared where the wire-flux combination is approved solely for the two-run technique.

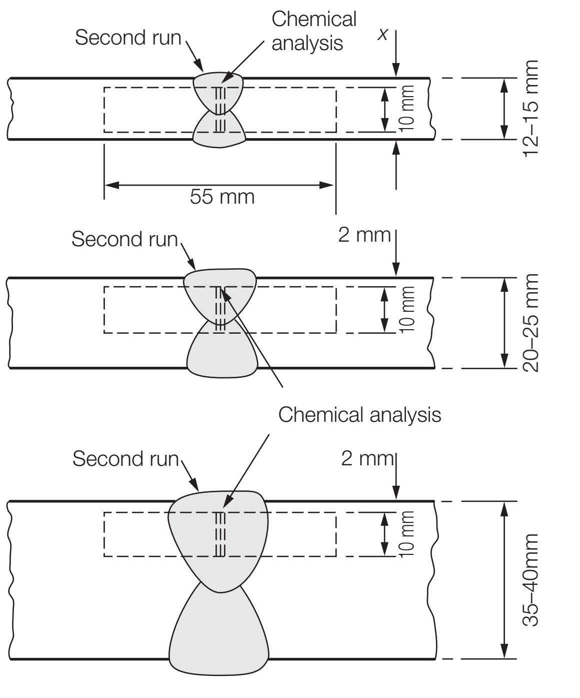


Fig. 11.4.4
Butt weld test assembly (two-run technique): position of impact test specimens

4.7.4 Where a wire-flux combination is approved for welding a range of steels with different specified minimum strength levels, steel of the highest strength approved is to be used for the preparation of the butt weld assembly required by 4.7.1(b).

■ *Section 5*
Wires and wire-gas combinations for manual, semi-automatic and automatic welding

5.1 General

5.1.1 Wire-gas combinations and flux-cored or flux-coated wires (for use with or without a shielding gas) are divided into the following categories for the purposes of approval testing:

(a) For use in manual multi-run welding with the inert gas tungsten arc welding process (GTAW).
(b) For use in semi-automatic multi-run metal arc welding.
(c) For use in single electrode multi-run automatic metal arc and GTAW welding.
(d) For use in single electrode two-run automatic metal arc and GTAW welding.

5.1.2 The term ‘manual’ is used to describe the technique where the gas-shielded tungsten arc torch is held in one hand and the filler is added separately by the other hand.

5.1.3 The term ‘semi-automatic’ is used to describe processes in which the weld is made manually by a welder holding a gun through which the wire is continuously fed.

5.1.4 In the GTAW process, ‘automatic’ refers to the fully mechanised control and application of both torch and separate filler wire.

5.1.5 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

5.1.6 A suffix S will be added after the grade mark to indicate approval for semi-automatic multi-run welding.

5.1.7 For wires intended for automatic welding, the suffixes T or M will be added after the grade mark to indicate approval for two-run or multi-run welding techniques, respectively.

5.1.8 For wires intended for both semi-automatic and automatic welding, the suffices will be added in combination.

5.1.9 Solid wire-gas combinations are considered naturally low hydrogen in character and qualify for ‘H15’ approval without testing. This is not so for cored wires and continuous coated wires which must be tested if there is a need for low hydrogen approval. For the lower strength grades of steel, low hydrogen testing is not normally a requirement for approval. With higher strength steels, it is more important and Table 11.5.1 shows the mandatory minimum low hydrogen status required for approval of wire-gas combinations.

5.1.10 The testing methods to be used for low hydrogen approval are to be in accordance with 3.4, modified to use the manufacturer's recommended welding conditions and adjusting the deposition rate to give a weld deposit weight per sample similar to that deposited when using manual electrodes.

5.1.11 Where applicable, the approved combination will name either the specific gas composition or its trade name, but in either case the composition of the shielding gas is to be reported. Unless otherwise agreed, additional approval tests are required when a shielding gas is used other than that used for the original approval tests. However a wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

5.1.12 Wires and wire-gas combinations for multiple electrode automatic welding will be subject to separate approval tests. Any proposals are to be submitted for consideration.

5.1.13 Wires and wire-gas combinations approved with multi-run technique for normal and higher strength levels up to and including ‘Y’ are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

Table 11.5.1 Minimum low hydrogen approval requirements for wires and wire-gas combinations

Approval grade	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for T technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (*see* Note 2)	NR	NR
2Y40 to 4Y40	H15	NR	H15
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
$1^1/_2$ Ni	H15	H15	NR
$3^1/_2$ Ni	H15	H15	NR
5 Ni	NR (*see* Note 3)	NR	NR
9 Ni	NR (*see* Note 3)	NR	NR

NOTES
1. NR – Not required, but approval can be sought, if desired.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

5.1.14 Wires and wire-gas combinations approved with multi-run technique for strength levels between Y40 and up to and including Y50 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

5.1.15 Wires and wire-gas combinations approved with multi-run technique for strength levels Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

5.1.16 Wires and wire-gas combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 5.4.1.

5.2 Approval tests for manual and semi-automatic multi-run welding

5.2.1 Approval tests for manual (GTAW) and semi-automatic multi-run welding are to be carried out generally in accordance with the requirements of Section 3, except as required by 5.2, using the respective technique for the preparation of all test assemblies. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.2.2 Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one using the smallest diameter, and the other using the largest diameter of wire for which approval is required. Where only one diameter is manufactured, only one deposited metal assembly is to be prepared.

5.2.3 The weld metal is to be deposited according to the practice recommended by the manufacturer, and the thickness of each layer of weld metal is to be between 2 mm and 6 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

5.2.4 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.2.5 Butt weld assemblies as shown in Fig. 11.3.2 are to be prepared for each welding position for which the wire is to be approved. In the case of approvals for normal and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), tests satisfying the requirements in both the downhand and vertical-upward positions will be considered as having also satisfied the requirements for the horizontal-vertical position.

5.2.6 The downhand assembly is to be welded using, for the first run, wire of the smallest diameter to be approved and, for the remaining runs, wire of the largest diameter to be approved.

5.2.7 Where approval is requested only in the downhand position, an additional butt weld assembly is to be prepared in that position using, if possible, wires of different diameter from those required by 5.2.6. If only one wire diameter is to be approved, this second downhand butt weld should be made using either larger or smaller beads than the first assembly.

5.2.8 The butt weld assemblies, in positions other than downhand, are to be welded using, for the first run, wire of the smallest diameter to be approved, and for the remaining runs, the largest diameter of wire recommended by the manufacturer for the position concerned.

5.2.9 Fillet weld test assemblies as detailed in 3.5 are to be prepared, examined and tested.

5.2.10 Low hydrogen approval tests are to be carried out if required by 5.1.9.

5.2.11 Test specimens from each assembly are to be prepared and tested in accordance with the requirements of 3.2 and 3.3.

5.3 Approval tests for multi-run automatic welding

5.3.1 Approval tests for multi-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.3, using the multi-run automatic welding technique for the preparation of all test assemblies.

5.3.2 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1. Welding is to be as detailed in 4.3.3, except that the thickness of each layer is to be not less than 3 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

5.3.3 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2 for each welding position to be approved for the automatic multi-run technique.

5.3.4 Test specimens from each test assembly are to be prepared and tested in accordance with the requirements of Section 4 for multi-run submerged-arc automatic welding.

5.3.5 Low hydrogen approval tests are to be made if required by 5.1.9.

5.3.6 At the discretion of LR, wires approved for semi-automatic welding may also be approved without additional tests, for use in multi-run automatic welding.

5.4 Approval tests for two-run automatic welding

5.4.1 Approval tests for two-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.4, using the two-run automatic welding technique for the preparation of all test assemblies. Two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

5.4.2 Two butt weld test assemblies are to be prepared generally as detailed in 4.5 and 4.6 using plates 12 to 15 mm and 20 to 25 mm in thickness.

5.4.3 If approval is requested for welding plate thicker than 25 mm, one assembly is to be prepared using plates approximately 20 mm in thickness and the other using plates of the maximum thickness for which approval is requested.

5.4.4 The edge preparation of the test assemblies is to be as shown in Fig. 11.5.1. Small deviations in edge preparation may be allowed, if these form part of the consumable manufacturer's recommendations. For assemblies using plates over 25 mm in thickness, the edge preparation is to be reported for information.

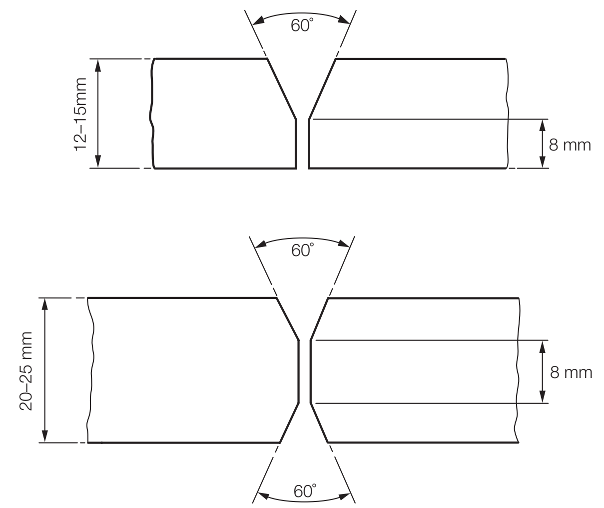


Fig. 11.5.1
Normal edge preparation for two-run butt weld test assemblies

5.4.5 The diameters of wires used are to be in accordance with the recommendations of the manufacturer and are to be reported.

5.4.6 Test specimens from each butt weld assembly are to be prepared and tested in accordance with the requirements of Section 4 for two-run submerged-arc automatic welding.

5.4.7 The weld metal chemical analysis is to be reported as in 4.6.9. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.5 Annual tests

5.5.1 Annual tests are to consist of at least the following:

(a) Wires approved for manual welding or semi-automatic welding or either of these combined with approval for automatic multi-run welding:
  one deposited metal test assembly prepared in accordance with 5.2 using a wire of diameter within the approved range.

(b) Wire approved for automatic multi-run welding:
  one deposited metal test assembly prepared in accordance with 5.3 using a wire of diameter as stated in (a).

(c) Wires approved for two-run automatic welding:
  one butt weld test assembly prepared in accordance with 5.4 using plates 20 to 25 mm in thickness or the maximum approved thickness. The diameter of wire used is to be reported.

Section 6
Consumables for use in electro-slag and electro-gas welding

6.1 General

6.1.1 The requirements for the approval of consumables used for electro-slag or electro-gas welding (including consumable nozzles, where applicable) are generally as detailed in Section 4 for two-run submerged-arc welding consumables, except as otherwise detailed in this Section.

6.1.2 For each grade, approval may be restricted for use with specific compositional types of steel. For Grades 1Y, 2Y, 3Y, 4Y, 2Y40, 3Y40 and 4Y40 this will normally be in respect of the grain refining element content, and tests on niobium grain refined steel will normally qualify for use also on steels treated with aluminium or vanadium or combinations of these elements.

6.1.3 Each strength level requires separate approval involving the welding and testing of two butt weld assemblies of different thickness. The greater thickness will determine the maximum approved thickness.

6.2 Butt weld test assemblies

6.2.1 Two butt weld test assemblies are to be prepared, one with plates 20 to 25 mm in thickness and the other with plates 35 to 40 mm in thickness. The steel used is not to be of any higher grade (impact toughness) than that for which approval is required. The limitations of 6.1.2 need to be considered in this Section. The chemical composition of the plate, including the content of grain refining elements, is to be reported.

6.2.2 The welding conditions and the edge preparation adopted are to be in accordance with the recommendations of the manufacturer and are to be reported in detail. The manufacturer's maximum recommended gap between plates is to be used in making the test assemblies.

6.2.3 It is recommended that the assemblies are subjected to radiographic examination to identify any defects before the preparation of any test specimens.

6.2.4 Test specimens as follows, and as shown in Fig. 11.6.1, are to be prepared from each test assembly:
(a) Two longitudinal tensile test specimens.
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) One macro-section.
(e) Two sets of three impact test specimens notched in accordance with Fig. 11.6.2.

6.2.5 The chemical analysis of the weld metal in each assembly is to be determined and reported. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

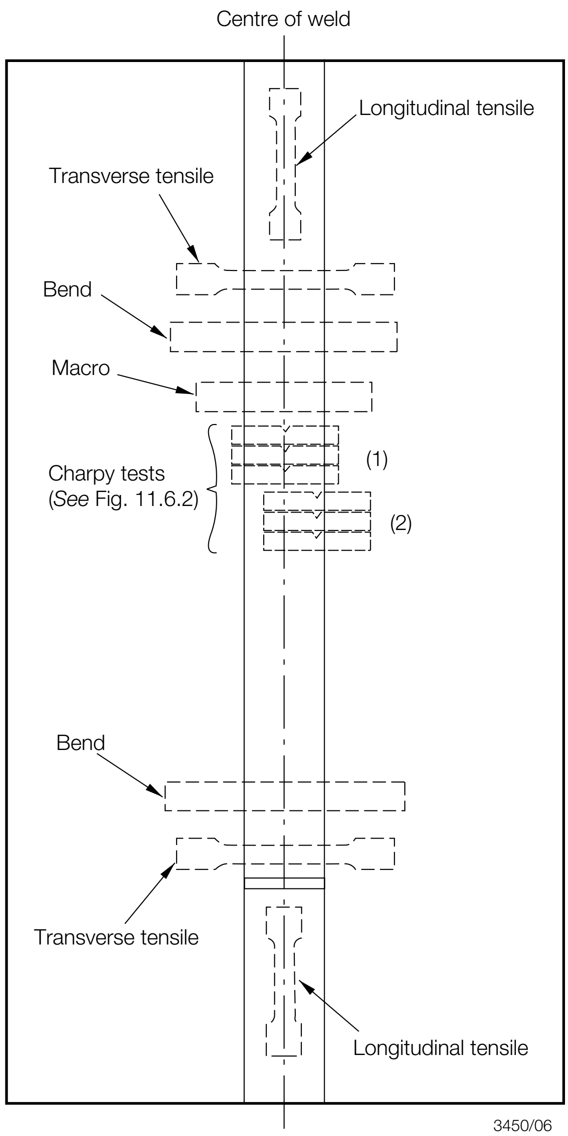


Fig. 11.6.1
Butt weld test assembly for electro-slag or electro-gas welding

6.2.6 The results of all transverse tensile and impact tests are to comply with the requirements given in Table 11.4.3 as appropriate. The position of fracture of the transverse tensile test is to be reported. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

6.2.7 The results of all longitudinal tensile tests are to comply with the requirements of Table 11.4.2.

6.2.8 The bend test specimens are to be in accordance with 4.6.7 and Table 11.4.3. Each surface of the weld is to be tested in tension.

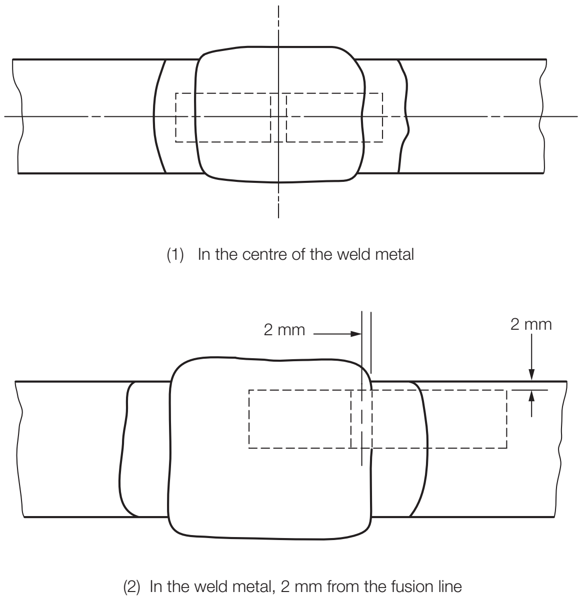


Fig. 11.6.2
Position of Charpy V-notch impact test specimens

6.3 Annual tests

6.3.1 Annual tests are to consist of at least one butt weld test assembly using plate material 20 to 25 mm in thickness.

6.3.2 The assembly is to be prepared and tested in accordance with 6.2 except that only the following tests are required:
(a) One longitudinal tensile test.
(b) One transverse tensile test.
(c) Two bend tests.
(d) One set of three Charpy V-notch impact tests with the specimens notched at the centre of the weld (position (1) in Fig. 11.6.2).
(e) Chemical analysis.

6.3.3 Where a consumable or combination is approved for a range of steels with different specified minimum strength levels, steel of the highest strength level is to be used for the preparation for the assembly required by 6.3.1.

■ *Section 7* Consumables for use in one-side welding with temporary backing materials

7.1 General

7.1.1 The requirements for approval of combinations including temporary backing material, for use in one-side welding techniques, are dependent on the technique used and which basic technique it most closely follows. The following are provided for:
(a) Technique m – for manual electrode/backing combinations.
(b) Technique S – for wire-gas/backing combinations used with semi-automatic multi-run technique.
(c) Technique M – for wire-flux or wire-gas in combination with backing material (and maybe supplementary filler materials) used with an automatic multi-run technique.
(d) Technique A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

7.1.2 For technique m, S or M, a single butt weld is to be made in plate of 20–25 mm thickness. For technique A, two butt welds are to be made, one in plate of the maximum thickness recommended by the manufacturer, the other in plate of approximately half the thickness of the first. Usually this will involve thicknesses in the region of 35–40 mm and 20–25 mm respectively.

7.1.3 A wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide content is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

7.1.4 Any unrecognized techniques or unusual combinations will be considered for approval subject to a test programme to be agreed based on the details of the technique and combination which are to be submitted in advance.

7.1.5 Where low hydrogen approval is required either by Table 11.7.1 or by the manufacturer, it should be noted that this will generally be achieved through separate testing of:
(a) the backing material, and
(b) the welding electrode or combination of wire-flux or wire-gas.

7.1.6 The hydrogen potential of the backing material is to be determined using the modified Gayley-Wooding method which expresses the total hydrogen content as water by weight per cent. The qualifying levels are:

To qualify as:	H_20 g/100g sample
H15	0,5
H10	0,3
H5	0,2

7.1.7 The sampling and approval of the combinations without the backing are to follow the general requirements of Sections 3, 4 or 5, as appropriate.

7.1.8 Combinations approved with multi-run technique (m, S and M) for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

Table 11.7.1 Minimum low hydrogen approval requirements for one-side welding with combinations including temporary backing material

Approval grades	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for A technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (*see* Note 2)	NR	NR
2Y40 to 4Y40	H15	H15	NR
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
$1^1/_2$ Ni	H15	H15	NR
$3^1/_2$ Ni	H15	H15	NR
5 Ni (*see* Note 3)	NR	NR	NR
9 Ni (*see* Note 3)	NR	NR	NR

NOTES
1. NR – Not required, but approval can be sought, if desired.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes the use of an austenitic, non-transformable, filler material.

7.1.9 Combinations approved with multi-run technique (m, S and M) for strength levels between Y40 and up to and including Y50 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

7.1.10 Combinations approved with multi-run technique (m, S and M) for strength levels Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

7.1.11 Combinations approved for the 'A' multi-run technique are not considered suitable for welding steels of any other strength level with that technique.

7.2 Approval tests for manual (m), semi-automatic (S) and automatic multi-run (M) techniques

7.2.1 For each position to be approved, one butt weld assembly is to be prepared using plates of 20–25 mm thickness as shown in Fig. 11.7.1. The grade of plate used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

7.2.2 The edge preparation and welding conditions are to be in accordance with the recommendations of the manufacturers.

7.2.3 Test specimens are to be prepared as shown in Fig. 11.7.1 and Fig. 11.7.2(a):
(a) One longitudinal tensile test specimen (from the centre of the weld).
(b) Two transverse tensile specimens.
(c) Two bend test specimens.
(d) One macrosection.

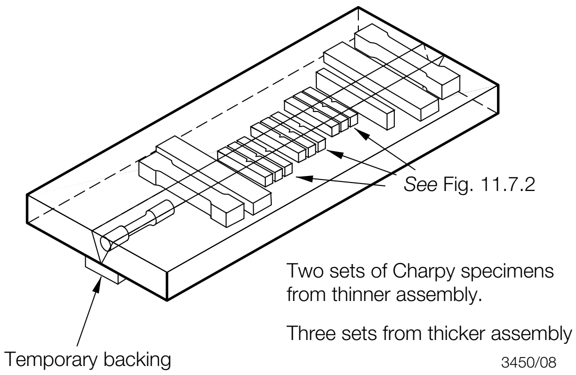


Fig. 11.7.1
Butt weld test assembly and specimens for all techniques

(e) Two sets of three Charpy impact test specimens positioned and notched in accordance with Fig.11.7.2(a). The bend specimens are to be tested, one with the face in tension, the other with the root in tension.

7.2.4 The results of all transverse tensile, bend and impact tests are to comply with the requirements in Table 11.3.3 for m and S technique, and Table 11.4.3 for M technique. The position of fracture of the transverse tensile test is to be reported. The appearance of the bend test specimens is to be in accordance with 3.3.12.

7.2.5 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2.

7.2.6 Low hydrogen approval is required in accordance with Table 11.7.1.

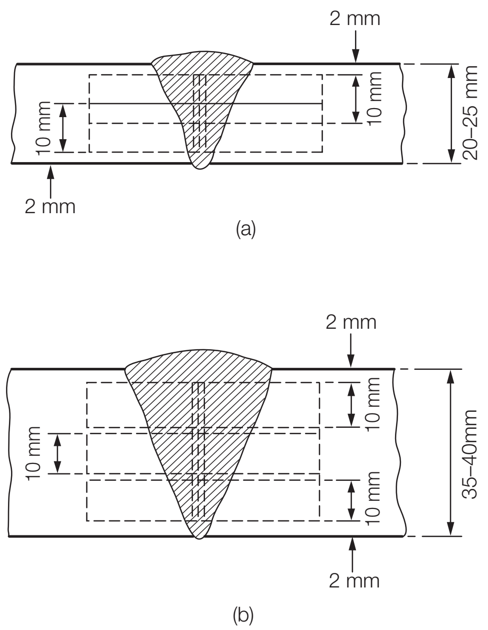


Fig. 11.7.2
Position of Charpy V-notch impact tests for one-side automatic welding

7.2.7 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the uppermost and lowest Charpy specimens. These are to be supplied by the manufacturer and are to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

7.3 Approval tests for high heat input automatic (A) techniques

7.3.1 Two butt weld assemblies are to be prepared, usually one of 35–40 mm thickness, the other 20–25 mm, as shown in Fig. 11.7.1, noting that in the thinner assembly only two sets of Charpy specimens are required. The grade of plates used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

7.3.2 The edge preparation and welding conditions are to be in accordance with the manufacturer's recommendations, and are to be reported to LR.

7.3.3 Test specimens as follows are to be prepared as shown in Fig. 11.7.1 and Figs. 11.7.2(a) and (b):
(a) One longitudinal tensile test specimen (from centre of weld).
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) One macro-section.
(e) From assembly 20 to 25 mm thick, two sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(a).
(f) From assembly 35 to 40 mm thick, three sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(b).

The bend specimens are to be tested, one with the face in tension, the other with the root in tension.

7.3.4 The results of all transverse tensile, bend and impact tests are to comply with the requirements of Table 11.4.3. The appearance of the bend test specimens is to be in accordance with 3.3.12. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

7.3.5 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2, except that for Grades 1Y, 2Y and 3Y the tensile strength is to be not less than 490 N/mm^2.

7.3.6 Low hydrogen approval is required in accordance with Table 11.7.1.

7.3.7 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the uppermost and lowest Charpy specimens in the thinner plate weld. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

7.4 Annual tests

7.4.1 Annual tests are to consist of, at least, one butt weld test assembly, for each technique approved, using plates of 20 to 25 mm thickness.

7.4.2 The assembly is to be prepared and tested in accordance with 7.2 or 7.3, as appropriate, except that only the following tests are required:
(a) One longitudinal tensile test (from centre of weld).
(b) One transverse tensile test.
(c) Two bend tests.
(d) One set of three impact tests taken from the root of the weld and the specimens notched in accordance with Fig. 11.7.2.
(e) Chemical analysis (one only).

■ *Section 8*
Consumables for welding austenitic and duplex stainless steels

8.1 General

8.1.1 Tests for the approval of consumables intended for welding the austenitic and duplex stainless steels detailed in Ch 3,7 are to be carried out generally in accordance with the Section (3, 4, 5, 6 or 7) relevant to the type of consumable or combination.

8.1.2 Approval will be indicated by the grade or grades of parent stainless steel for which the consumable or combination is approved.

8.1.3 Where a shielding gas is employed separate approval will be required for each specific shielding gas composition.

8.1.4 Consumables for welding the austenitic stainless steels and the duplex stainless steels to carbon or carbon-manganese steels will be approved in a similar manner. Parent plate used for the butt and fillet weld test assemblies will be carbon or carbon-manganese steel with either austenitic stainless steel or duplex stainless steel, as appropriate. Approval will be indicated by 'SS/CMn' and 'Dup/CMn' respectively.

8.1.5 Separate approval will be given for welding chemical and cryogenic applications. For chemical use, evidence of relevant corrosion resistance will be required. Charpy impact toughness tests will be required for all uses, but for cryogenic use the Charpy impact toughness requirements are more severe.

8.1.6 The welding technique will be indicated in the approval grading by a letter:

- m – for manual SMAW or GTAW welding.
- S – for wire-gas combinations used with a semi-automatic multi-run technique.
- M – for wire-flux or wire-gas combinations used with an automatic multi-run technique.
- T – for wire-flux or wire-gas combinations used with an automatic two-run technique.
- A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

8.2 Deposited metal test assemblies

8.2.1 Where the relevant Section requires deposited metal assemblies to be made and tested, the plates used must be either of the type for which approval is required or of normal strength carbon, or carbon-manganese steel with the prepared edges built up with stainless steel weld metal and finished with a layer of weld metal from the consumable to be approved.

8.2.2 The chemical analysis of the deposited weld metal is to be reported, including all significant elements. The elements reported will be dependent on the type of stainless steel for which approval of the consumables is requested. Any unusual weld metal compositions will have to be justified in respect of the particular approval requested. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

8.2.3 The results of all tensile and notch impact tests are to comply with the requirements given in Table 11.8.1 as appropriate.

8.2.4 The ferrite content in the last weld run from each deposited metal assembly is to be determined by physical or metallographic means, and reported, indicating the method of determination.

Table 11.8.1 Requirements for deposited metal tests (manual, semi-automatic and automatic multi-run techniques)

Grade	0,2% proof stress N/mm^2 minimum	1% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on 50 mm % minimum	Charpy V-notch impact tests: Chemical test temperature °C	Charpy V-notch impact tests: Cryogenic test temperature °C	Charpy V-notch impact tests: Average energy *See* Note 1 J minimum
304L	270	310	500	25	–20	–196	29
304LN	305	345	530	22	–20	–196	29
316L	270	310	500	22	–20	–196	29
316LN	305	345	530	22	–20	–196	29
317L	305	345	530	22	–20	–196	29
317LN	340	380	570	22	–20	–196	29
321	290	330	550	22	–20	–196	29
347	290	330	550	22	–20	–196	29
S 31254	370	410	650	22	–20	–196	29
N 08904	270	310	500	22	–20	–196	29
SS/CMn	270	310	500	22	–20	–60	29
S 31260	485	525	690	20	–20	*see* Note 2	40
S 31803	450	490	620	25	–20	*see* Note 2	40
S 32550	550	590	760	15	–20	*see* Note 2	40
S 32750	550	590	800	15	–20	*see* Note 2	40
S 32760	550	590	750	25	–20	*see* Note 2	40
Dup/CMn	270	310	500	22	–20	*see* Note 2	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Approval for cryogenic applications is to be obtained at the procedure approval stage.

Table 11.8.2 Requirements for butt weld tests (all techniques)

Grade	Tensile strength N/mm^2 minimum	Bend test ratio: $\frac{D}{t}$	Weld ferrite content %	Charpy V-notch impact tests		
				Chemical test temperature °C	Cryogenic test temperature °C	Average energy (*see* Note 1) J minimum
304L	500	3	4–12	–20	–196	27
304LN	530	3	4–12	–20	–196	27
316L	500	3	4–12	–20	–196	27
316LN	530	3	4–12	–20	–196	27
317L	530	3	4–12	–20	–196	27
317LN	570	3	4–12	–20	–196	27
321	550	3	4–12	–20	–196	27
347	550	3	4–12	–20	–196	27
S 31254	650	3	(*see* Note 2)	–20	–196	27
N 08904	500	3	(*see* Note 2)	–20	–196	27
SS/CMn	500	3	4–12	–20	–60	27
S 31260	690	4	35–65	–20	(*see* Note 3)	40
S 31803	620	3	35–65	–20		40
S 32550	760	6	35–65	–20		40
S 32750	800	6	35–65	–20		40
S 32760	750	6	35–65	–20		40
Dup/CMn	500	3	(*see* Note 2)	–20	(*see* Note 3)	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. To be reported for special consideration.
3. Approval for cryogenic applications is to be obtained at the procedure approval stage.

8.3 Butt weld test assemblies

8.3.1 Where the relevant Section requires butt weld assemblies to be made and tested, the plates used are to be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, provided the consumable is metallurgically compatible with the base material to be used, the prepared edges are to be built up with a layer of weld metal before final machining of the weld preparation.

8.3.2 The results of transverse tensile, notch impact and bend tests are to comply with the requirements of Table 11.8.2 as appropriate. The position of fracture is to be reported to LR.

8.3.3 The ferrite content at the centre of the weld metal in each butt weld assembly is to be determined by physical or metallographic means, and meet the requirements in Table 11.8.2. The method of determination is to be reported.

8.3.4 For austenitic and duplex stainless steel approvals (except for types 304L, 316L, 321 and 347), an appropriate sample from each butt weld assembly is to be submitted to the corrosion testing provided in ASTM G48, Method ‘C’. The results are to be reported so as to allow confirmation of the maximum acceptable pitting corrosion resistance temperature. This will be part of the approval grading and will be set at 5°C intervals. The minimum pitting corrosion temperature would not be expected to be less than 20°C.

8.4 Fillet weld test assemblies

8.4.1 Where the relevant Section requires fillet weld assemblies to be made and tested, the plates used must be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, the surfaces on which the fillet weld beads are to be deposited are to be cut back by machining and then built up to original dimensions with weld metal from the consumable to be approved.

8.4.2 The ferrite content at the centre of the weld metal in each fillet weld bead of each assembly is to be determined from the centre macro-section by physical or metallographic means, and reported. The method of determination is also to be reported to LR.

8.4.3 Where approval is sought for fillet welding only, corrosion testing is to be carried out in accordance with 8.3.4 from a sample taken from the deposited metal test assembly.

8.5 Annual tests

8.5.1 Annual tests are to be carried out as required by the relevant Section appropriate to the type of consumable and welding technique.

8.5.2 The results of all tests are to comply with the requirements given in Table 11.8.1 and Table 11.8.2 as appropriate.

Section 9 Consumables for welding aluminium alloys

9.1 General

9.1.1 Tests for the approval of consumables intended for welding the aluminium alloys detailed in Chapter 8 are to be carried out generally in accordance with the requirements of Sections 1, 2 and 5, except as otherwise detailed in this Section.

9.1.2 Approval will be indicated by the grade shown in Table 11.9.1.

Table 11.9.1 Requirements for butt weld tests

Consumable Approval Grade (*see* Note 1)	Base material used for the test	Tensile strength N/mm^2 minimum	Bend test ratio $\frac{D}{t}$
LR RA/LR WA	5754	190	3
LR RB/LR WB	5086	240	6
LR RC1/LR WC1	5083	275	6
LR RC2/LR WC2 (*see* Note 2)	5383 or 5456	290	6
LR RC3/LR WC3 (*see* Note 2)	5059	330	6
LR RD/LR WD (*see* Note 4)	6005A 6061 6082	170 170 170	6 6 6

NOTES
1. The prefixes ‘R’ and ‘W’ indicate ‘rod’ form (for Gas Tungsten Arc Welding (GTAW)) or ‘wire’ form (for Gas Metal Arc Welding (GMAW) and GTAW).
2. Approval of grade LR RC2/LR WC2 confers approval of 5383, 5456 and 5083 base material grade.
3. Approval of grade LR RC3/LR WC3 confers approval of 5059, 5383, 5456 and 5083 base material grades.
4. Approval of grade LR RD/LR WD confers approval of 6005A, 6061 and 6082 base material grades.

9.1.3 The welding technique will be indicated in the approval grading by a letter:

m – manual multi-run welding (GTAW),
S – semi-automatic multi-run welding (GMAW),
M – automatic multi-run welding (GTAW or GMAW),
T – automatic two-run welding (GMAW).

9.1.4 The compositions of the shielding gas and the filler/electrode wire are to be reported.

9.1.5 Approval granted using the multi-run technique for a specific filler/electrode wire with a gas in one of the groups listed in Table 11.9.2 will extend to any other gas compositions within that same group, provided that the gas composition is within the range recommended by the consumable manufacturer, subject to agreement with LR.

Table 11.9.2 Shielding gas compositions

Group	Gas composition (Vol. %) (*see* Note)	
	Helium	Argon
I-1	–	100
I-2	100	–
I-3	>0 ≤33	Remainder
I-4	>33 ≤66	Remainder
I-5	>66 ≤95	Remainder
S	Special gas	

NOTE
Gases of other composition (mixed gases) or special purity may be considered as special gases and will require separate approval tests.

9.1.6 Approval granted for the two-run technique will be for a specific shielding gas composition; additional tests may be required if a change in shielding gas composition is sought.

9.1.7 On completion of welding, assemblies are to be allowed to cool naturally to ambient temperature. Welded test assemblies and test specimens are not to be subjected to any heat treatment after welding except for the alloy Grades 6005A, 6061 and 6082. These are to be allowed to naturally age at ambient temperature for a period of 72 hours from the completion of welding, before testing is carried out. A second solution heat treatment is not permitted.

9.1.8 All butt test assemblies are to be subjected to both radiographic and visual examination and imperfections such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks assessed in accordance with Intermediate Level C of ISO 10042, aided where necessary by dye penetrant and ultrasonic examination.

9.1.9 Fillet weld test assemblies and macro-sections are to be visually examined for imperfections, such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks, in accordance with Intermediate Level C of ISO 10042, aided where necessary by radiographic and dye penetrant examination.

9.2 Approval tests for manual, semi-automatic and automatic multi-run techniques

9.2.1 Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies.

9.2.2 The welding parameters are to be within the range recommended by the manufacturer and are to be reported.

9.2.3 Welded assemblies are to be prepared and tested in accordance with 9.3, 9.4 and 9.5.

9.3 Deposited metal test assembly

9.3.1 One assembly is to be prepared in the downhand position as shown in Fig. 11.9.1.

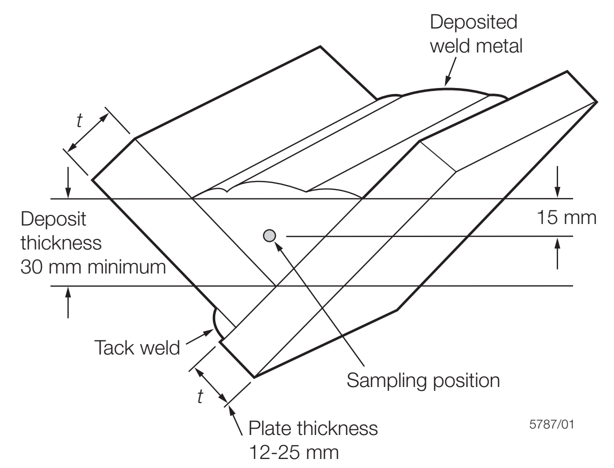


Fig. 11.9.1 Deposited metal test assembly

9.3.2 The chemical composition of the plate used for the assembly is to be compatible with the weld metal.

9.3.3 The thickness of the plate used, and the length of the assembly, are to be appropriate to the welding process. The plate thickness is to be not less than 12 mm.

9.3.4 For the approval of filler wire/gas and electrode wire/gas combinations for manual or semi-automatic welding by GTAW or GMAW, one test assembly is to be welded using any size of wire within the range for which approval is sought.

9.3.5 For automatic multi-run approval, one test assembly is to be welded by the respective process using the recommended diameter of wire.

9.3.6 The weld metal is to be deposited in multi-run layers in accordance with normal practice. The direction of deposition of each layer is to alternate from each end of the plate.

9.3.7 The deposited weld metal in the assembly is to be analysed and reported including the contents of all significant elements. The elements reported will be dependent on the type of aluminium alloy for which approval of the consumables is requested. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

9.4 Butt weld test assemblies

9.4.1 Plate of the corresponding type of aluminium alloy and of an appropriate thickness is to be used for the preparation of the test assemblies.

9.4.2 In order to ensure sound and representative welds, it is essential that test assemblies are cleaned and degreased prior to welding. Assemblies as shown in Fig. 11.9.2 are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the consumable is recommended by the manufacturer; except that consumables satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. Any wire diameter(s) to be approved may be used.

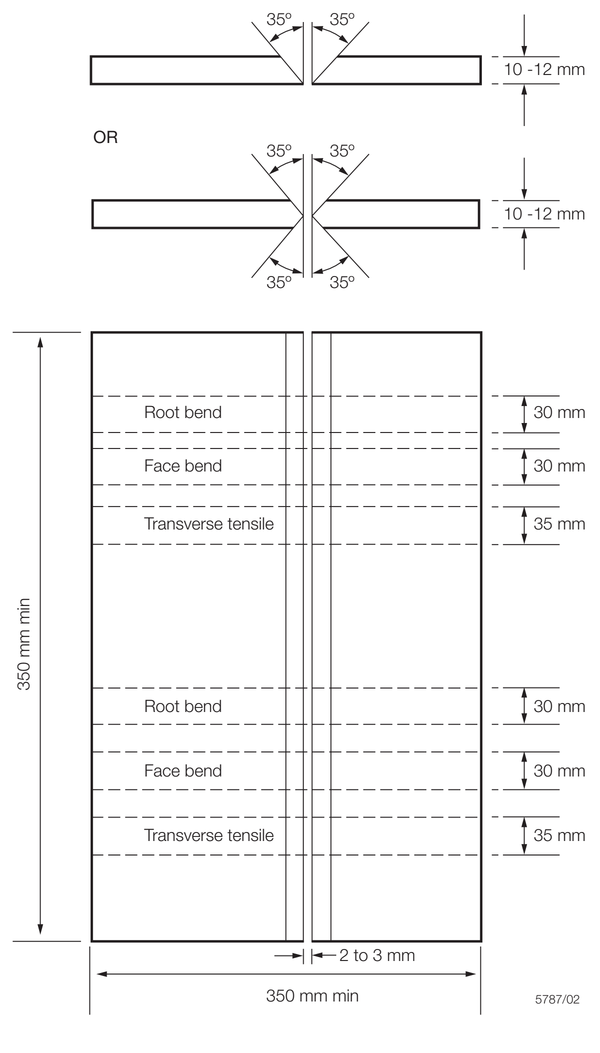


Fig. 11.9.2
Butt weld test assembly
(positional, multi-run technique)

9.4.3 One assembly, as shown in Fig. 11.9.3, is to be prepared for welding in the downhand position. The assembly is to be welded using, for the first run, wire of the smallest diameter recommended by the manufacturer and, for the remaining runs, wire of the largest diameter to be approved.

9.4.4 The welding conditions are to be in accordance with the recommendations of the manufacturer and are to be reported in detail.

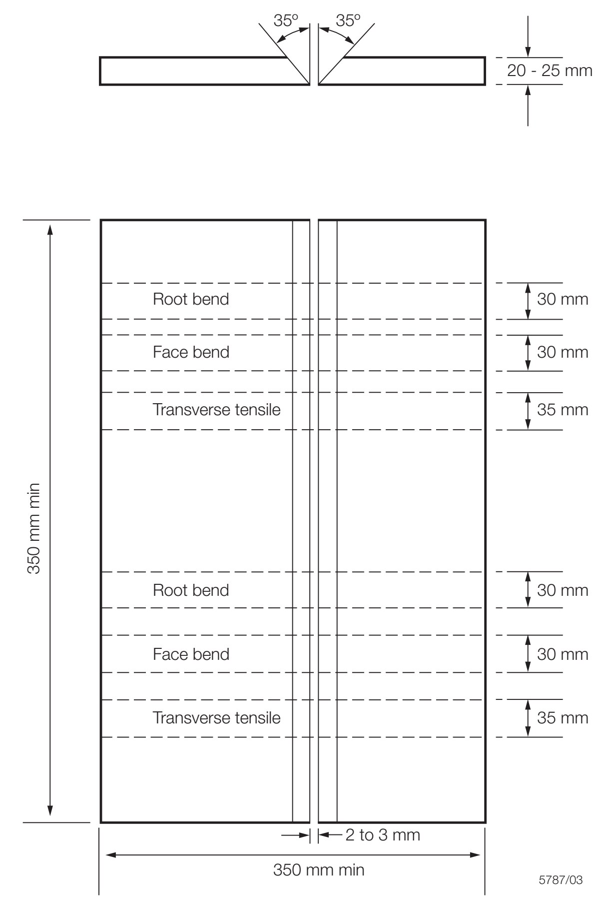


Fig. 11.9.3
Butt weld test assembly
(downhand, multi-run technique)

9.4.5 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.4.6 The test specimens are to be taken from the welded assemblies as shown in Fig. 11.9.2 and Fig. 11.9.3. For each assembly they are to comprise:

- 2 transverse tensile specimens;
- 2 face bend specimens; and
- 2 root bend specimens.

9.4.7 All tensile test specimens are to have a tensile strength not less than the respective value shown in Table 11.9.1. The position of each fracture is to be reported.

9.4.8 The bend test specimens are to be bent around a former having a diameter not more than the number of times the thickness of the test specimen, as shown in Table 11.9.1, and can be considered as complying with the requirements if, after bending to an angle of not less than 180°, no crack or other open defect exceeding 3 mm in length can be seen on the outer surface. Flaws appearing at the corners of a test specimen may be ignored.

9.4.9 In order to obtain uniform bending of the bend test specimens, it is recommended that the wrap-around or guided bend test using a roller method is employed.

9.5 Fillet weld test assembly

9.5.1 One assembly is to be prepared and welded in the horizontal-vertical position and tested in accordance with the appropriate requirements of 3.5, except that the plates are to be of an aluminium alloy compatible with the weld metal, that no hardness tests are required and that for automatic multi-run approval only one fillet weld bead is to be made using the recommended wire diameter. In this case, the bead size is to be as large as the maximum single bead size recommended by the manufacturer for fillet welding.

9.5.2 The results of examination of the macro-specimens and the fractured fillet welds are to be reported in accordance with 3.5.3 and 3.5.5. Imperfections are to be assessed in accordance with 9.1.9.

9.6 Approval tests for two-run technique

9.6.1 Two butt weld test assemblies are to be prepared using the following plate thicknesses:

(a) one with the maximum thickness for which approval is requested,
(b) one with a thickness approximately one half to two thirds that of the maximum thickness.

9.7 Butt weld test assemblies (two-run technique)

9.7.1 The plates used are to be of the aluminium alloy appropriate to the approval required as shown in Table 11.9.1. The composition of the plate material is to be within the range specified for that alloy in Table 8.1.3 in Chapter 8 and is to be reported including all significant elements.

9.7.2 The wire diameter, edge preparation, welding current, arc voltage and travel speed are to be in accordance with the manufacturer's recommendations and are to be reported.

9.7.3 Each butt weld is to be made in two runs, one from each side. After completion of the first run, the assembly is to be left in still air until it has cooled to less than 50°C.

9.7.4 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.7.5 The test specimens as shown in Fig. 11.9.4 are to be prepared from each test assembly. The edges of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. Each cut in the assembly is also to be examined to confirm that complete fusion and penetration have been achieved.

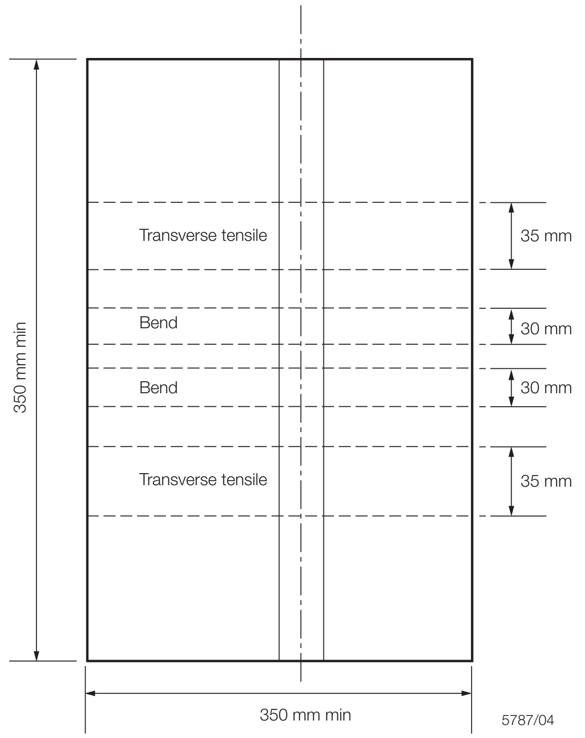


Fig. 11.9.4
Butt weld test assembly (two-run technique)

9.7.6 The results of the transverse tensile tests are to be as in 9.4.7 and of the bend tests as in 9.4.8. The position of the fracture in each transverse tensile specimen is to be reported.

9.8 Annual tests

9.8.1 Annual tests are to consist of the following:

(a) for combinations approved for the multi-run technique, one deposited metal assembly in 9.3 and one downhand butt assembly in 9.4;

(b) for combinations approved for the two-run technique, one butt weld assembly in plate material of thickness equal to one half to two thirds that of the maximum thickness approved.

9.8.2 For the automatic two-run technique, one butt weld assembly is to be prepared and tested in accordance with 9.7.

Fabricated Steel Sections

Section

■ *Section 1* General

1.1 Scope

1.1.1 This Chapter gives requirements for structural steel sections manufactured from flat products by automatic welding and intended for use in the construction of ships and other structures.

1.1.2 These items are to be manufactured in accordance with the general requirements of Chapter 1 and the requirements of this Chapter.

1.1.3 Products which comply with National or International specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or are approved for a specific application. In all cases, surveys are to be carried out in accordance with the requirements of Chapter 1 with certification in accordance with 1.4. Items are to be manufactured at works which have been approved by Lloyd's Register (hereinafter referred to as 'LR') for the type of product, grade of steel and dimensions being supplied.

1.2 Dimensional tolerances

1.2.1 Products are to conform dimensionally with the provisions of an acceptable National or International Standard.

1.3 Identification of products

1.3.1 Every finished item is to be clearly marked by the manufacturer in at least one place with LR's brand Ʀ and the following particulars:
(a) The manufacturer's name or trade mark.
(b) Identification mark for the grade of steel.
(c) Identification number and/or initials which will enable the full history of the item to be traced.
(d) If required by the purchaser, his order number or other identification mark.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognizable.

1.3.2 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be unmistakably defaced, *see also* Ch 1,4.8.

1.4 Certification

1.4.1 Each test certificate or shipping statement is to include the following particulars:
(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Description and dimensions of the product.
(e) Specification or grade of the steel.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples of constituent plates.
(h) Mechanical test results of constituent plates (not required on shipping statements).
(j) Condition of supply when other than as-rolled.
(k) Make and brand of welding consumables.

1.4.2 Before the test certificates or shipping statements are signed by the Surveyor, the manufacturer is required to provide a written declaration stating that the product has been made by an approved procedure, and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor, or an authorized deputy. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the works and signed by an authorized representative of the manufacturer:

> 'We hereby certify that the material has been made by an approved procedure in accordance with the Rules of Lloyd's Register and has been satisfactorily tested in the presence of LR's representative.'

■ *Section 2* Materials

2.1 Plate

2.1.1 The products are to be manufactured using plate or wide flats meeting the requirements of Chapter 3, Section 2, 3 or 6 as applicable.

2.1.2 Plate material used for welded construction may be subject to significant strains in a direction perpendicular to the rolled surfaces. Where thick plates are used for flanges, consideration should be given to the use of special plate material with specified through thickness properties. Requirements for this material are detailed in Ch 3,8.

2.2 Welding consumables

2.2.1 Welding consumables are to be approved in accordance with Chapter 11.

■ *Section 3* Manufacture

3.1 Specifications and preparation

3.1.1 Prior to the initial approval of a works, a manufacturing specification is to be prepared and approved by LR. This manufacturing specification should cover as a minimum the following operations:

(a) Inspection and control of incoming material.
(b) Edge preparations.
(c) Assembly of components and jigging.
(d) Welding procedures.
(e) Rectification of weld defects.
(f) Straightening procedures, if any.
(g) Final heat treatment, if any.

3.1.2 Plate preparation procedures are to be such that any edges left unwelded are free from cracks or other deleterious imperfections. Procedure tests are to be carried out to confirm this.

3.1.3 Assembly jigs and clamping devices are to be such that the specified welding gaps and clearances are reproduced consistently. If hydraulic pressure devices are used for bringing the web into contact with the flanges, means are to be provided to ensure that the hydraulic pressure does not fall below that previously determined as necessary to obtain the specified degree of contact.

3.2 Welding

3.2.1 Welding is to be double continuous fillet welding or full penetration butt weld. The throat thickness of fillet welds is to be determined from:

Throat thickness = t x 0,34

where

t = plate thickness of the thinner member to be joined (generally the web).

In no case is the throat thickness to be less than 3 mm.

NOTE
Fabricated sections are items which are used in place of rolled sections, as such they will not be regarded as sub-assemblies. Products regarded as sub-assemblies subject to LR's Rules are to be welded in accordance with the relevant Rules.

3.2.2 Where an approved procedure of deep penetration welding is used, the throat thickness will be specially considered taking into consideration the depth of penetration.

3.2.3 The leg length of the weld is to be not less than 1,4 times the specified throat thickness.

3.2.4 Where either the web or flange is of higher tensile steel the following additional requirements are to be complied with:

(a) Where the carbon equivalent, calculated from the ladle analysis and using the formula given below, is in excess of 0,45 per cent, approved low hydrogen higher tensile electrodes and preheating are to be used. Where the carbon equivalent is above 0,41 per cent but is not more than 0,45 per cent, approved low hydrogen higher tensile electrodes are to be used, but preheating will not generally be required except under conditions of high restraint or low ambient temperature. Where the carbon equivalent is not more than 0,41 per cent, any type of approved higher tensile electrodes may be used and preheating will not generally be required.

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

This formula is applicable only to steels which are basically of the carbon-manganese type containing minor quantities of grain refining elements, for example, niobium, vanadium or aluminium. The proposed use of low alloy steels will be subject to special consideration.

(b) Welding procedures and techniques are to be demonstrated as satisfactory by tests.

3.2.5 Procedures are to be established for the welding of all joints. These are to specify the welding method and welding parameters, type and make of consumable, edge preparation, root gap and welding position proposed. LR will require sample joints to be prepared under conditions similar to those which will be obtained during manufacture.

3.2.6 Welding plant and appliances are to be suitable for the purpose intended and are to be maintained in an efficient condition. Satisfactory storage facilities for consumables are to be provided close to working areas.

3.2.7 Welding operators are to be proficient in the type of work on which they are engaged. A sufficient number of skilled supervisors is to be provided to ensure effective control at all stages of assembly and welding operations.

3.2.8 The consumables used are to be approved by LR and are to be suitable for the type of joint and grade of steel as follows:

For normal strength steels (as defined in Chapter 3):

Grade 3	For welding any combination of grades.
Grade 2	For welding any combination of grades other than Grade E to Grade E.
Grade 1	For welding Grade A.

For higher tensile steels (as defined in Chapter 3):

Grade 3Y	For welding any combination of grades.
Grade 2Y	For welding any combination of grades other than Grade EH to Grade EH.
Grade 1Y	For welding Grade AH. (Not available as electrodes for manual welding.)

For the joining of two different grades of steel of the same tensile properties, consumables suitable for the lower grade are acceptable. For the joining of steel of different tensile strengths, the consumables are to be suitable for the tensile strength of the component considered in the determination of weld size, *see* 3.2.1.

3.2.9 Where primers are applied over areas which will subsequently be welded, they are to be of a quality accepted by LR as having no significant deleterious effect on the finished weld under the welding conditions proposed. Alternatively, primer is to be removed in way of the weld.

3.2.10 In production welding, the diameter of electrode, current, voltage, rate of deposit and number of runs are to conform, without significant variation, to those established in accordance with 3.2.5. Provision is to be made for checking the current in the vicinity of the arc.

3.2.11 It is preferable that tack welds should be avoided. When used, tack welding is to be equal in quality to the finished welds. Where deep penetration welding is used for manufacture, procedure tests shall demonstrate that the penetration is achieved in way of any tack welds left in place.

3.2.12 The surfaces of all parts to be welded are to be clean, dry and free from rust, scale and grease. Where multi-run welding is used, the surface of each run of the deposit is to be thoroughly cleaned and free from slag before the succeeding run is deposited.

■ *Section 4* Inspection and testing

4.1 Visual examination

4.1.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer and are to be carried out on all material prior to despatch. Acceptance by the Surveyor of material later found to be defective shall not absolve the manufacturer from this responsibility.

4.1.2 The Surveyors are to make random checks to ensure that the weld size and profile are in accordance with the manufacturing specification and the manufacturer's Quality Control Procedures. This examination is to include inspection of undercut which is not to exceed the limits given in Table 12.4.1.

4.2 Non-destructive examination

4.2.1 The manufacturer is to examine by magnetic particle or dye penetrant methods the welds for a length of 200 mm at each end of each length cut for delivery.

4.2.2 If any cracks are revealed, the whole of the length is to be examined by magnetic particle or dye penetrant methods. Corrective action in respect of the manufacturing process and repairs are to be as indicated in the manufacturer's Quality Control Manual and to the satisfaction of the Surveyor.

4.3 Destructive tests

4.3.1 For each batch presented, one macro specimen is to be taken from near the beginning of the production run and one from near the end. If the batch exceeds 500 m total length, an additional two macro specimens are to be taken from each quantity of 500 m or fraction thereof. The macro specimens are to be etched to allow checking that the weld penetration is in accordance with the manufacturing specification.

Table 12.4.1 Weld defect acceptance levels for fabricated steel sections

Defect type	Permitted maximum
Undercut	Intermittent undercut is permitted, provided the depth does not exceed 0,4 mm
Cracks/lamellar tears	Not permitted
Lack of root fusion	Not permitted
Lack of side fusion	Not permitted
Lack of inter run fusion	Not permitted
POROSITY	
Uniformly distributed porosity	Not permitted
SLAG	
Individual and parallel to weld axis	L = 25 mm W = 1,5 mm max.
Linear group	Aggregate length not to exceed 25 mm in a length of 100 mm
Symbols	
L = length of defect W = width of defect	
NOTE LR is prepared to accept other recognized International or National Standards relating to construction, welding and acceptance criteria provided such standards are substantially similar to those laid down in these Rules. Where it is intended to utilise such standards, the acceptance of the standard should be agreed prior to the commencement of construction.	

4.3.2 From each batch, two lengths of 100 mm shall be taken, and for each pair of fillet welds one shall be machined off and the sample shall be bent in such a way as to break the other weld with its root in tension. The fractured surfaces should be examined for compliance with the requirements of Table 12.4.1. If the batch exceeds 500 m total length, additional such specimens shall be tested for each quantity of 500 m or part thereof.

4.3.3 For the purposes of 4.3.1 and 4.3.2, a batch is to consist of products of only one size and grade of material.

4.3.4 Weld defect acceptance levels are given in Table 12.4.1.

4.4 Records

4.4.1 The manufacturer is to maintain records by which sources of material can be identified together with the results of all inspections.

■ *Section 1* General

1.1 Scope

1.1.1 This Chapter gives the requirements for the manufacture of fabricated steel machinery such as fabricated bases and other supporting structures for large machines, fabricated casings and products such as earth moving machinery. It is not intended to apply to bridges, constructional steel work, cranes, modules or other items specifically covered in other LR Rules.

1.2 Construction

1.2.1 The fabrications are to be surveyed at the manufacturer's works. The general level of workmanship where no detailed requirements are given in this Chapter is to be to the Surveyor's satisfaction.

1.2.2 The Surveyor is to test the materials and examine the workmanship from the commencement of work until the final test. Any defects are to be indicated as early as possible. On completion, an appropriate Certificate will be issued.

1.3 Documents for submission

1.3.1 Before work is commenced, the following documents are to be submitted for appraisal, in triplicate:
(a) Plans sufficient to identify the manufacturing procedure.
(b) Manufacturing specification, *see also* 7.2.2.
(c) Weld procedure specifications, *see also* 7.6.
(d) Weld procedure qualification test plans, *see also* 7.6.
(e) Non-destructive inspection procedures.
(f) Manufacturer's procedure for recording test results, including welder approval tests.
Subsequent alterations to any of these documents, materials or manufacturing procedures are to be re-submitted for consideration.

1.4 Materials

1.4.1 The materials used in the construction are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, and the appropriate Sections in Chapters 3, 4 and 5 and of this Chapter. Materials for which provision is not made therein may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.

■ *Section 2* Steel selection

2.1 Scope

2.1.1 This Section gives the requirements for the selection of steel.

2.2 Basis of selection

2.2.1 Materials are to be selected in accordance with the requirements of the design in respect of static strength, fatigue strength and fracture resistance as appropriate.

2.2.2 Adequate static strength is to be confirmed by specifying yield stress, tensile strength and elongation.

2.2.3 Adequate fatigue strength is normally assured in the design process and by considering established fatigue data for constructional details in specified materials. It is not normally required to carry out fatigue tests as part of the materials specification.

2.2.4 The resistance to fracture is controlled, in part, by the notch toughness of the steel used in the structure. Steels are to be selected with a suitable level of notch toughness. The level required is, in general, related to the temperature at which it is to be used, the thickness and yield strength of the material, and the stress pattern associated with its location (which will be influenced by any post weld stress relief heat treatment applied to a weldment).

2.2.5 When plate material intended for welded construction will be subjected to significant strains in a direction perpendicular to the rolled surfaces, material with specified through thickness ductility is to be used. These strains are usually associated with restraint during welding, with thicker plates, and with thermal contraction. They may also be associated with loads applied in service or during construction. Where these strains are of sufficient magnitude, lamellar tearing may occur, *see* Ch 3,8.

2.3 Impact test requirements

2.3.1 Impact tests are required when the design temperature is 0°C or lower.

2.3.2 The impact test temperature is to be derived from the design temperature and the material thickness by the use of Fig. 13.2.1.

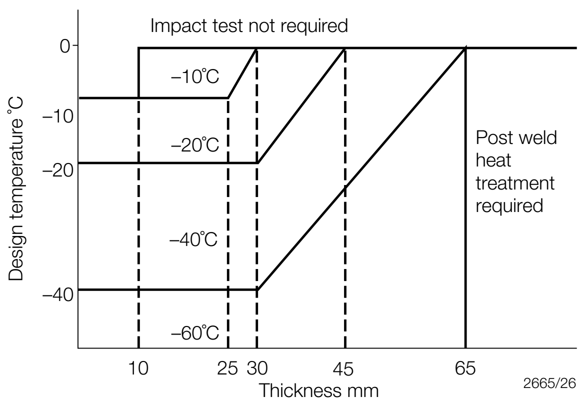


Fig. 13.2.1
Impact test temperatures related to design temperature and thickness

2.3.3 Minimum energy absorption in the Charpy test is to be related to the minimum specified yield strength of the material according to Table 13.2.1. For materials of yield strength higher than covered by this Table, the minimum energy absorption in Joules is to be one tenth of the specified minimum yield strength in N/mm^2.

Table 13.2.1 Charpy impact energy requirements for structural components for design temperatures 0°C and lower

Specified minimum yield stress not above N/mm^2	Minimum required energy absorption J
215	21
235	27
315	31
345	34
415	41

2.3.4 Fabrications whose thicknesses exceed 65 mm are to be subjected to a post weld heat treatment. Impact tests when required by 2.3.1 are to be made on specimens heat treated in the same manner as the fabrication, *see* Section 8. Test temperatures are to comply with Table 13.2.2 and the energy absorption requirements are to be in accordance with 2.3.3.

Table 13.2.2 Charpy impact test temperatures for post weld heat treated structural components for design temperatures of 0°C and lower

Thickness mm	Charpy impact test temperature related to design temperature
up to 25	equal
26 – 100	10°C below
NOTE Requirements for components with thicknesses in excess of 100 mm are subject to agreement.	

■ *Section 3*

Rolled steel materials

3.1 Scope

3.1.1 This Section gives the general requirements for hot rolled plates, bars and sections intended for use in the construction of fabricated machinery and structures.

3.1.2 These items are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, Ch 3,1 and of this sub-Section.

3.1.3 As an alternative to 3.1.2, materials which comply with International or National specifications may be accepted, provided that these specifications give reasonable equivalence to the requirements of this Chapter or, alternatively, are approved for a specific application. In these cases, survey and certification are to be carried out in accordance with the requirements of Chapters 1 and 2.

3.2 Plate material with through thickness properties

3.2.1 Plate material with specified through thickness ductility is to be in accordance with Ch 3,8.

3.3 Manufacture

3.3.1 The method of deoxidation is to comply with the requirements given in Table 13.3.1.

3.4 Dimensional tolerances

3.4.1 Thickness tolerances are to be in accordance with ISO 7452 Class B.

3.4.2 The minus tolerance on sections (except for wide flats) is to be in accordance with the requirements of an approved International or National specification.

Table 13.3.1 Deoxidation practice and condition of supply

Specified impact test temperature	Deoxidation	Thickness mm	Condition of supply
Down to 0°C	Any except rimmed steel	All	Any
Down to −10°C	Semi-killed or killed	≤ 25	Any
		> 25	Normalized, controlled rolled T.M.C.P. (*see* Note) or quenched and tempered
Below −10°C	Fully killed and fine grain treated	All	Normalized, controlled rolled T.M.C.P. (*see* Note) or quenched and tempered

NOTE
T.M.C.P. = Thermomechanically controlled processes (*see* Ch 3,2.3.2)

3.5 Condition of supply

3.5.1 All materials are to be supplied in a condition complying with the requirements given in Table 13.3.1. Where alternative conditions are permitted, these are at the option of the steelmaker unless otherwise expressly stated in the order for the material. The condition of supply is to be stated on the test certificate.

3.6 Chemical composition

3.6.1 Where carbon-manganese steels are used they are to comply with Table 13.3.2.

3.6.2 The compositions of alloy steels are to comply with the specification submitted for consideration.

3.6.3 For carbon-manganese steels where impact properties are specified, the carbon equivalent is to be calculated from the ladle analysis and is not to exceed the maximum value agreed with the steelmaker when the steel is ordered. If no other formula is specified for the carbon equivalent, it is to be calculated using the following formula:

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

and is not to exceed the value given in Table 13.3.2. This formula is applicable only to steels which are basically of the carbon-manganese type containing minor quantities of grain refining elements, such as niobium, vanadium or aluminium.

3.7 Mechanical tests

3.7.1 Mechanical tests are to be made in accordance with Chapter 2.

3.7.2 The test results are to comply with the approved specification.

Table 13.3.2 Chemical composition of carbon-manganese steels

Element	Content % max.
Carbon	0,23
Manganese	1,65
Silicon	0,10 – 0,50
Sulphur	0,04 (*see* Note 1)
Phosphorus	0,04
Copper	0,35
Chromium	0,20
Nickel	0,40 (*see* Note 2)
Molybdenum	0,08
Aluminium (acid soluble)	0,015 min. (*see* Notes 4 and 5)
Niobium	0,015 – 0,05 (*see* Note 5)
Vanadium	0,03 – 0,10 (*see* Note 5)
Carbon equivalent	0,43 (*see* Note 3)

NOTES
1. For steels with specified through thickness properties, maximum sulphur should be 0,015%.
2. For steels for use at temperatures below 0°C, nickel levels above 0,40% will be given special consideration.
3. For steels with specified minimum yield stress over 360 N/mm^2, may be up to 0,45%.
4. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
5. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.

3.7.3 Where required by 2.3, Charpy V-notch impact tests are to be made in accordance with the following:
(a) Where the specified impact test temperature is not lower than minus 20°C one set of three specimens is to be made from the thickest piece in each batch.
(b) Where the specified impact test temperature is lower than minus 20°C one set of three specimens is to be made from each piece. For sections, strips or bars one set of three specimens is to be made from each 25 tonnes of rolled products or fraction thereof.

3.8 Rectification of defects

3.8.1 The requirements for the rectification of defects are given in Ch 3,1.10.

3.8.2 For plates which have been produced by T.M.C.P. and for quenched and tempered plates, repair by welding will be approved only after procedure tests have shown that the mechanical properties are not impaired.

3.9 Identification of materials

3.9.1 The particulars detailed in Ch 3,1.11 are to be marked on all materials which have been accepted. The system of identification is to comply with Ch 1,4.9.

3.10 Certification of materials

3.10.1 Certification is to comply with Ch 3,1.11.

3.10.2 In addition to the information detailed in Ch 3,1.11.1, where the maximum carbon equivalent is as specified in Table 13.3.2 this is to be stated.

■ *Section 4* Steel castings

4.1 Scope

4.1.1 This Section gives the requirements for steel castings intended for use in fabricated structures.

4.2 Requirements

4.2.1 Castings are to be manufactured and tested in accordance with Ch 4,1 together with the requirements of 4.2.2 and 4.2.3.

4.2.2 Where the design temperature is 0°C or below, castings are to conform to the requirements of 2.3.

4.2.3 The location of material for test is to be shown on the casting drawing submitted for approval.

■ *Section 5* Steel forgings

5.1 Scope

5.1.1 This Section gives the requirements for steel forgings intended for use in fabricated structures.

5.2 Requirements

5.2.1 Forgings are to be manufactured and tested in accordance with the requirements of Chapter 5 and this Section.

5.2.2 Forgings for use at design temperatures of 0°C or below are to conform with the requirements of 2.3.

5.2.3 Particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

5.2.4 The location of material for test is to be shown on the forging drawing submitted for approval.

■ *Section 6* Welding consumables

6.1 Scope

6.1.1 This Section gives the requirements for the welding consumables to be used.

6.2 Requirements

6.2.1 Approved welding consumables only are to be used in the fabrication of structures.

6.2.2 All consumables are to be approved in accordance with Chapter 11 or as part of the welding procedure qualification test.

6.2.3 Consumables are to be selected so that when used under the relevant conditions they deposit a weld metal whose yield strength and tensile strength are not less than the corresponding specified minimum values of the materials to be welded.

6.2.4 For the joining of two different grades of steel of the same tensile properties, consumables suitable for the lower grade are acceptable. For the joining of steel of different tensile strengths, the consumables are to be suitable for the tensile strength of the component considered in the determination of weld size.

6.2.5 Impact strength, where required, is to meet the requirements of 7.6.13 and 7.6.14.

■ *Section 7* Fabrication procedures

7.1 Scope

7.1.1 This Section gives the minimum essential requirements concerning control of manufacturing procedures so that the mechanical properties of the materials remain within the acceptable range.

7.1.2 In addition to the minimum requirements contained in this Section, the normal requirements of good manufacturing practice are to be met. The requirements given in this Section are not comprehensive and are concerned only with the maintenance of satisfactory metallurgical properties.

7.2 Manufacture

7.2.1 Construction is to be carried out at a works or site inspected and accepted by Lloyd's Register (hereinafter referred to as 'LR').

7.2.2 Prior to the commencement of fabrication, a manufacturing specification is to be prepared and submitted to the Surveyor for consideration. This manufacturing specification should cover as a minimum the following operations:
(a) Inspection and control of incoming material. (All materials are to be accompanied by certificates).
(b) Edge preparations.
(c) Assembly of components and jigging.
(d) Welding procedures.
(e) Non-destructive inspection procedures.
(f) Fabrication tolerances.
(g) Rectification of weld defects.
(h) Straightening procedures, if any.
(j) Post weld heat treatment, if any.

7.2.3 The manufacturer is to maintain records by which sources of material can be identified together with the results of all inspections.

7.3 Forming of steel plates and sections

7.3.1 Certain requirements in respect of forming of steel plates and sections by hot or cold working, and rectification of form by the use of line, spot and wedge heating are given in 7.3.2 to 7.3.9.

7.3.2 So far as possible, hot and cold forming is to be carried out by machine; forming by hammering with or without local heating, is not to be employed.

7.3.3 All plates which have been hot formed or locally heated for forming are to be normalized on completion of this operation. If, however, hot forming is carried out entirely at a temperature within the normalizing range, subsequent heat treatment will not be required for carbon-manganese steels. In both instances alloy steels may, in addition, be required to be tempered.

7.3.4 Forming is not to be continued at temperatures below the normalizing range, unless this has been demonstrated not to impair mechanical properties.

7.3.5 Where heating is used for fairing or forming a structure, the conditions of heating and cooling are to be such that the mechanical properties, especially the toughness, of the materials are not impaired.

7.3.6 Where material is supplied in the as-rolled or controlled rolled condition or which has been through a T.M.C.P. the maximum temperature during line heating is not to exceed 900°C and water cooling is not to be applied until the temperature has dropped to 550°C. Manufacturers should confirm, with supporting data, that the mechanical properties are not adversely affected.

7.3.7 For materials which are supplied in the normalized condition, two alternative temperature cycles are permissible:
(a) Heat to maximum temperature of 900°C and air cool to room temperature, or
(b) heat to maximum temperature of 650°C, air cool to 550°C, then water cool.

7.3.8 Where materials have been prefabricated prior to forming and assembly, no weld is to be heated above the temperature range approved for post weld heat treatment, *see* Table 13.8.1.

7.3.9 Where materials are to be formed essentially at room temperature, consideration is to be given to the possibility of strain age embrittlement. It is to be shown, either by testing or by reference to published information, that at the maximum strain to be imposed, there is no reduction in material toughness due to strain ageing.

7.3.10 Where the strain exceeds five per cent, the material is to be either:
(a) Normalized after rolling and before welding, or
(b) subjected to an effective post weld heat treatment
unless it is demonstrated that there is no reduction in toughness of the plate material, including the weld heat affected zone.

7.4 Edge preparation

7.4.1 The preparation of plate edges is to be accurate, uniform and smoothly finished.

7.4.2 All edges are to be free from cracks or other deleterious imperfections and any material damaged during preparation is to be cut back to sound material.

7.4.3 If alloy steels are prepared by flame cutting, the surface is to be dressed back by grinding or machining for a distance of about 2 mm, unless it has been shown that the material has not been damaged by the cutting process. Special examination will be required for cracks on the cut surfaces and the heat affected zones; preheating may be required to ensure satisfactory results when flame cutting.

7.4.4 The requirements detailed in 7.4.1 to 7.4.3 apply equally to those edges that are to be welded and those that are not.

7.5 Assembly for welding

7.5.1 All joints are to be accurately aligned and closed or adjusted in accordance with an approved joint design before welding.

7.5.2 Assembly jigs and clamping devices are to be such that the specified welding gaps and clearances are reproduced consistently. If hydraulic pressure devices are used, means are to be provided to ensure that the hydraulic pressure does not fall below that necessary to obtain the specified degree of contact.

7.5.3 Excessive force is not to be used in fairing and closing the work. Correction of irregularities is not to be done by hammering.

7.5.4 Provision is to be made for retaining the elements to be welded in correct alignment without rigid restraint; clamps, wedges and alignment jigs are to be so arranged as to allow freedom of lateral movement to occur between adjacent elements. Where excessive gaps exist between surfaces or edges to be joined, the corrective measures adopted are to be to the satisfaction of the Surveyor. Buttering may be used for this purpose, up to a maximum of 15 mm.

7.5.5 Tack welds are to be made in accordance with the root run requirements of the weld procedure specification approved for the joint and are to be inspected before incorporation or, alternatively, tack welds may be completely removed before completion of the root pass.

7.5.6 Where welded-on bridge pieces or other aids to fabrication are used, care is to be taken that the surfaces of the material are not left in a damaged condition after the attachments have been removed. Any necessary removal of attachments and rectification of scars by welding are to be undertaken before applying any required post-weld heat treatment.

7.5.7 The arrangement of material is to be such as will ensure structural continuity and alignment as specified on the drawings, particularly at intersections of load bearing members.

7.5.8 The maximum permissible values for misalignment of principal structural elements are to comply with Table 13.9.1.

7.6 Welding procedures and qualifications

7.6.1 Details of welded connections are to be clearly indicated on the plans submitted for approval (*see* 1.3) and should include the type and dimensions of the welds. Reference to the appropriate Welding Procedure Specification (W.P.S.) is also to be marked on the plans.

7.6.2 Structural arrangements are to be such as to allow adequate access for completion of all welding operations. Welded joints are to be so arranged as to facilitate the use of flat (downhand) welding wherever possible.

7.6.3 Consideration is to be given to the type and design of joint preparation, disposition of joints, weld bead sequence and joint completion sequence with a view to minimizing restraint and the risk of cracking in fabrication. Proposed procedures are to be agreed with LR prior to the commencement of fabrication.

7.6.4 W.P.S. and Procedure Qualification test plans are to be submitted to LR for review. Unless agreed otherwise, prequalified weld procedures are not acceptable.

7.6.5 The manufacturer's W.P.S. is to meet the requirements of this Section and is to be qualified in accordance with an International or a National Standard. Qualification procedures are to be carried out in the presence of the Surveyor who is also to witness the tests.

7.6.6 The W.P.S. is to contain the following minimum information, where tolerances are to be quoted for all variables:

(a) Welding processes used, including techniques and mode of operation.
(b) Material type and grade.
(c) Details of joint preparation, fit-up, and cleaning of surface involved in welding.
(d) Material thickness range and for pipe the outside diameter range.
(e) Welding position and, in the case of vertical welding, the direction of progression.
(f) Full details of welding consumables, parameters, arc type(s) and bead deposition sequences.
(g) Details of back-gouging requirements and means of achievement.
(h) Details of pre-heating and interpass temperatures and post-weld heat treatment (where applicable).
(j) Codes of practice specified if applicable.
(k) Treatment of tack welds.

7.6.7 The W.P.S. is also to state which controls are applied specifically for avoiding the various forms of cracking appropriate to the type of material. Confirmation is to be given where the procedure follows the recommendations or requirements of published documents, or where specially controlled materials have been included in the specification, and the source is to be quoted.

7.6.8 Welding Procedure Qualification tests are to be carried out to verify that the materials and method prescribed in the W.P.S. will produce weldments that are adequate for the intended application and meet the requirements of these Rules. Welding procedures applicable to plate are to be qualified by welding tests made with the welding direction parallel to the principal rolling direction.

7.6.9 Each Welding Procedure is to be qualified for each welding position in which it will be used in the fabrication. The test assemblies required to qualify different welding positions are given in Table 13.7.1. The welding positions are illustrated in Figs. 13.7.1 to 13.7.5.

7.6.10 On completion of welding, including any necessary post-weld heat treatment, the procedure qualification test assemblies are to be subjected to the non-destructive and applicable destructive tests detailed in Figs. 13.7.6 to 13.7.8. The test requirements for T, K and Y connections (*see* Fig. 13.7.5) are as follows:

A Visual examination
B Surface crack detection
C 100% ultrasonic examination
D From acute angle: one macro specimen, including hardness survey.

7.6.11 The results of the non-destructive examinations and mechanical tests are to comply with the approved manufacturing specification and with the requirements of this Chapter.

7.6.12 The yield stress and tensile strength of the weld assembly, as demonstrated by all-weld metal and transverse tensile tests, are to be not less than the minimum yield stress and tensile strength respectively of the parent material.

Table 13.7.1 Weld procedure qualification

Types of weld	Test assembly position (*see* Note 1)	Types of weld and welding positions qualified (*see* Note 2)			
		Plate		Pipe	
		Butt	Fillet	Butt	Fillet
Plate/butt	1G 2G 3G (*see* Note 3) 4G	F H V OH	F F, H V OH	F F, H	F F, H
Plate/fillet	1F 2F 3F (*see* Note 3) 4F		F F, H V OH		F F, H V OH
Pipe/butt	1G rotated 2G 5G 6G	F F, H F, V, OH F, H, V, OH	F F, H F, V, OH F, H, V, OH	F F, H F, V, OH F, H, V, OH	F F, H F, V, OH F, H, V, OH
Pipe/fillet	1F rotated 2F 2F rotated 4F 5F		F F, OH F, H F, H, OH All		F F, OH F, H F, H, OH All
T, Y, K connections	(*see* Note 4)			T, Y, K branch connections	

NOTES
1. Reference should be made to Figs. 13.7.1 to 13.7.5.
2. F = flat; V = vertical; H = horizontal; OH = overhead
3. Qualification for the 3G and 3F positions is limited to the direction of progression used in the test (*see* 7.6.6(e)).
4. The assembly is to be welded in the position specified in Fig. 13.7.5.
5. The material thicknesses qualified are from *T*/2 to 2*T*, where *T* is the thickness or the plate or pipe used in the test assembly. Where *T* is 25 mm or greater, the maximum thicknesses qualified are unlimited.

7.6.13 Where impact tests are required (*see* 2.3), the locations and orientation of individual Charpy V-notch test specimens are to comply with Fig. 13.7.9.

7.6.14 The impact tests are to be made at the same temperature as those for the parent material and the minimum absorbed energy is to equal that for the parent material.

7.7 Approval of welders

7.7.1 The responsibility for selection, training and testing of welding operators rests with the fabricator who is to test welding operators to a suitable International or National Standard.

7.7.2 Welders who have not used a particular process and equipment for a period exceeding six months are to be retested.

7.7.3 Welder approval test records are to be retained by the fabricator and are to be made available to the Surveyor when requested.

7.7.4 Welder approval tests utilizing the approved welding procedures are to be carried out to qualify the welders for each position on which they will be engaged. Table 13.7.2 details the possible qualification test assemblies that can be used to achieve the desired positional qualifications. Welders may be approved for T, K and Y connections by the use of a typical test assembly in the 6GR position for which a typical assembly is illustrated in Fig. 13.7.10.

7.7.5 The range of thicknesses or diameters of material for which the welder will be approved will relate to the thickness or diameter of the material used in the test assembly as indicated in Table 13.7.3 or Table 13.7.4 as appropriate.

7.7.6 Qualification obtained using the test assembly illustrated in Fig. 13.7.10 covers all thicknesses and diameters.

7.7.7 The completed test assembly is to be examined visually, supplemented when necessary by magnetic particle or dye penetrant inspection or by macroexamination. It is then to be subjected, as a minimum, to the appropriate tests listed in Table 13.7.5.

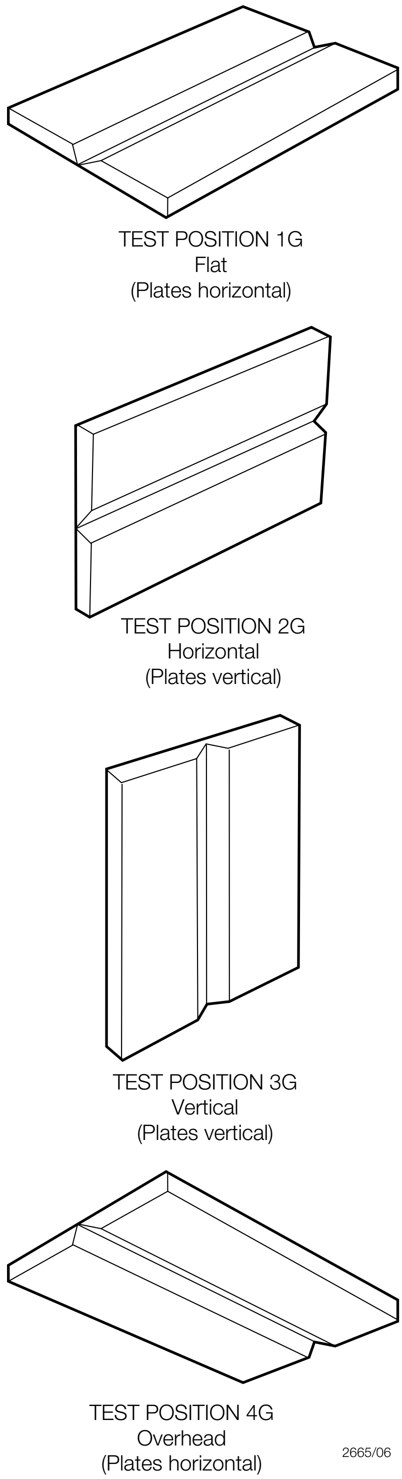


Fig. 13.7.1
Positions of test plates for plate assemblies

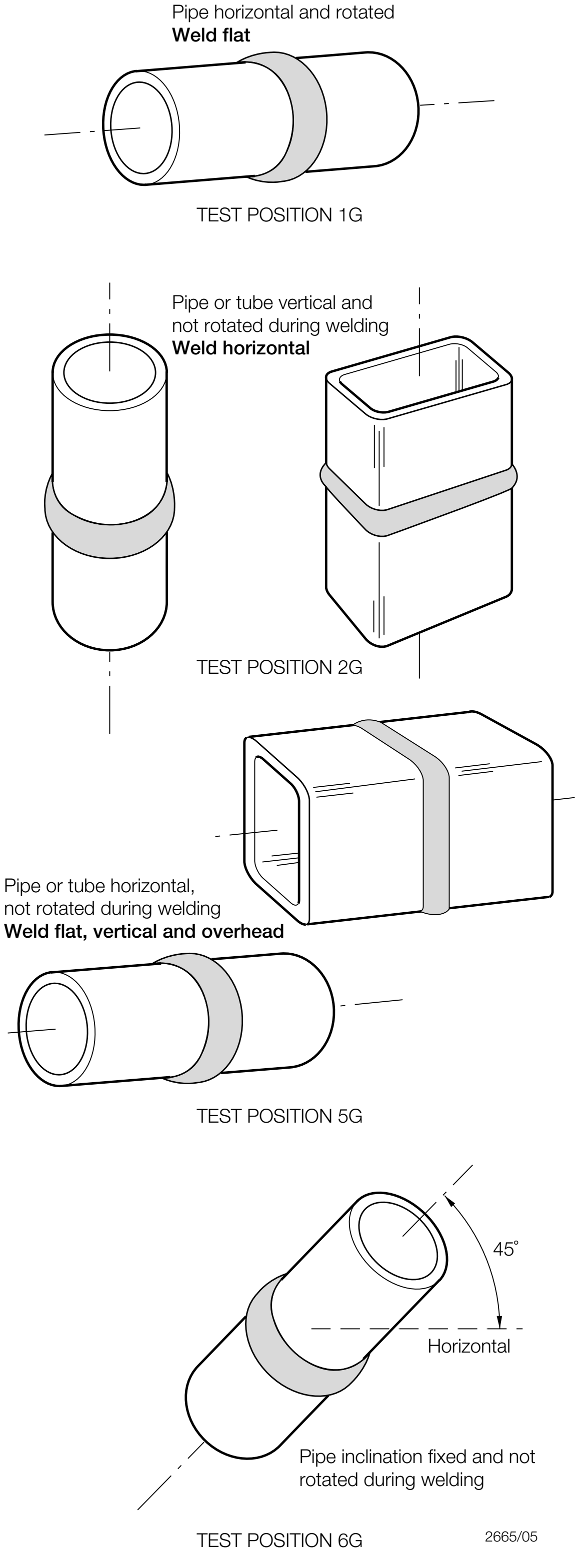


Fig. 13.7.2
Position of pipes and welds for qualification weld test assemblies

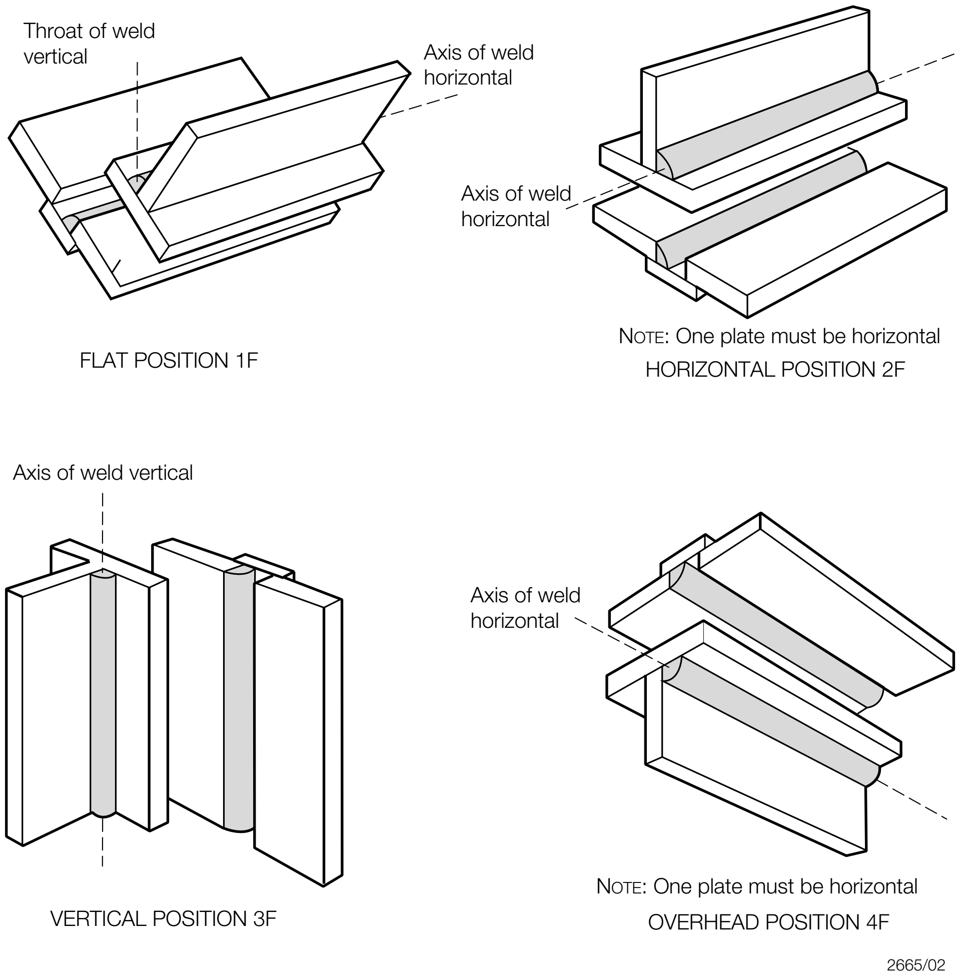


Fig. 13.7.3 Positions of test plates for fillet welds

7.8 Workmanship

7.8.1 Technically competent and suitably qualified direction and control are to be provided to ensure effective control at all stages of sub-assembly, assembly and welding operations.

7.8.2 Welding plant and appliances are to be suitable for the purpose intended and are to be maintained in an efficient condition. Suitable facilities are to be provided for the storage and preparation of welding consumables in accordance with the manufacturer's instructions. Appropriately controlled storage is to be provided local to the working areas.

7.8.3 In production welding, the diameter of electrode, current, voltage, rate of deposit and number of runs are to conform, without significant variation, to those established in accordance with 7.6.6. Provision is to be made for checking the current in the vicinity of the arc.

7.8.4 In the case of automatic welding, means are also to be provided for measuring the arc voltage.

7.8.5 All electrical plant used in connection with the welding operation is to be adequately earthed.

7.8.6 Adequate protection is to be provided where welding is required to be carried out in exposed positions in wet, windy or cold weather. In cold weather (below about 5°C) precautions are to be taken to warm the weldment to avoid condensation and screen where necessary to prevent rapid cooling of the weld; special care is to be taken when welding thick material and higher tensile steel. Unless otherwise agreed, electric resistance heaters or adequately controlled gas heaters are to be used for preheating.

7.8.7 Where primers are applied over areas which will subsequently be welded, they are to be of a quality accepted by LR as having no significant deleterious effect on the finished weld under the welding conditions proposed. Alternatively, primer is to be removed in way of the weld.

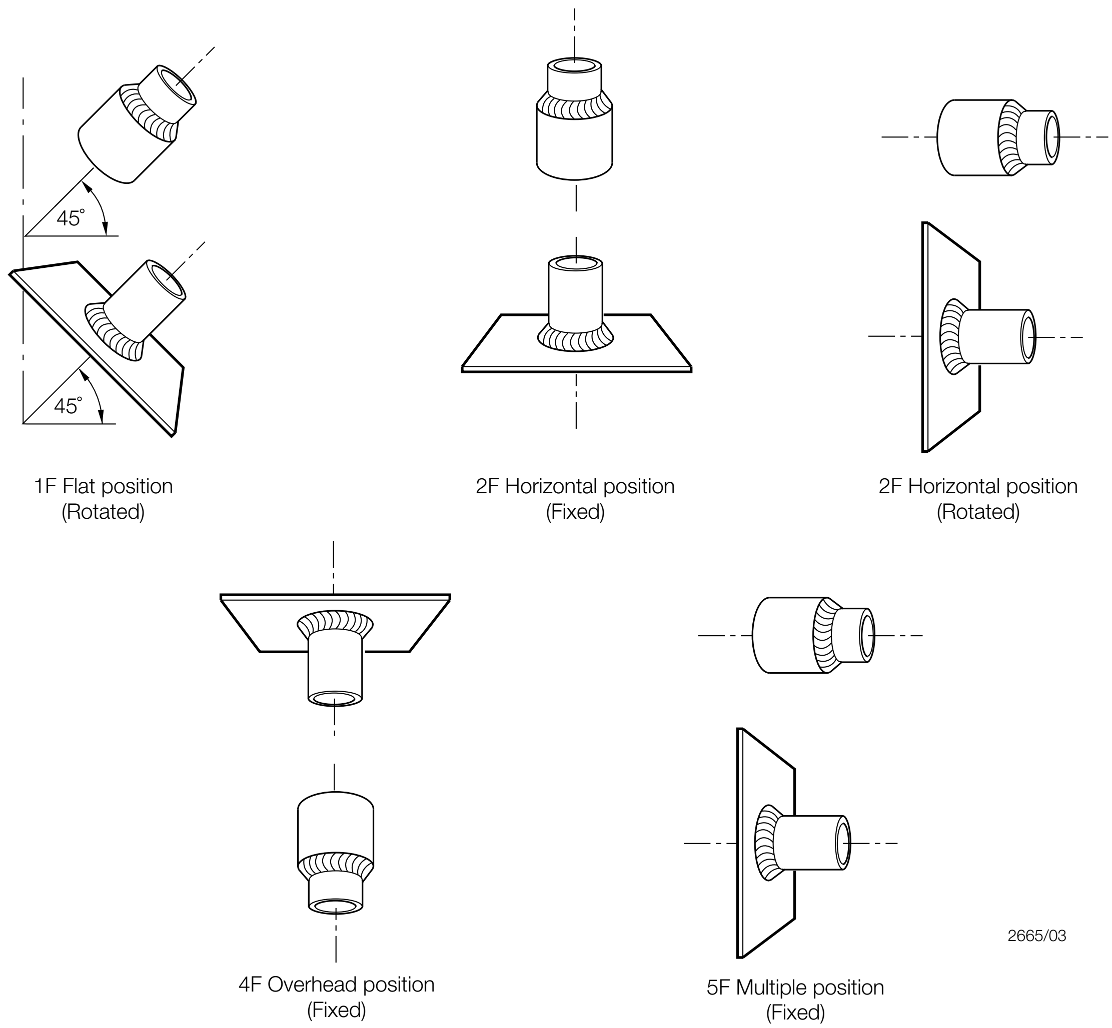


Fig. 13.7.4 Positions of test pipes for fillet welds

7.8.8 Welding is to proceed systematically with each welded joint being completed in correct sequence in accordance with the plans submitted (*see* 1.3.1(a)) without undue interruption. Where practicable, welding is to commence at the centre of a joint and proceed outwards or at the centre of an assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions. Generally, the welding of stiffener members including transverses, frames, girders, etc., to welded plate panels by automatic processes should be carried out in such a way as to minimize distortion.

7.8.9 Care is to be taken in respect to preheating and the prevention of rapid cooling and possible cracking when a repair invites the application of small weld beads.

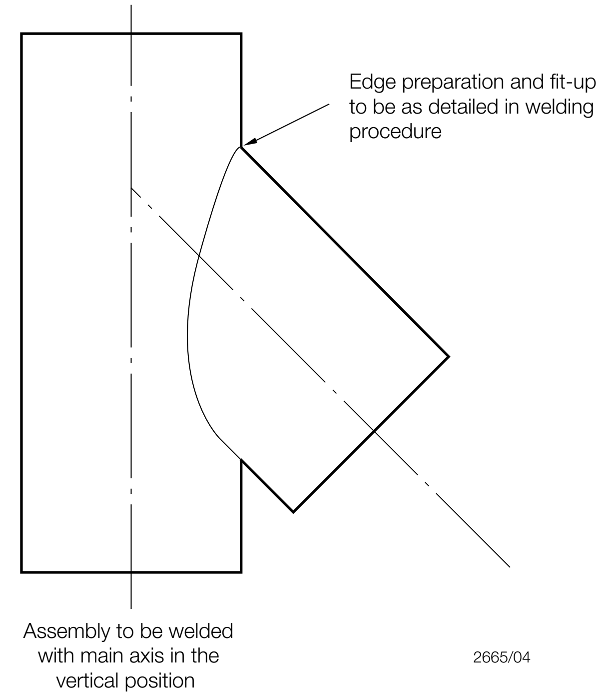
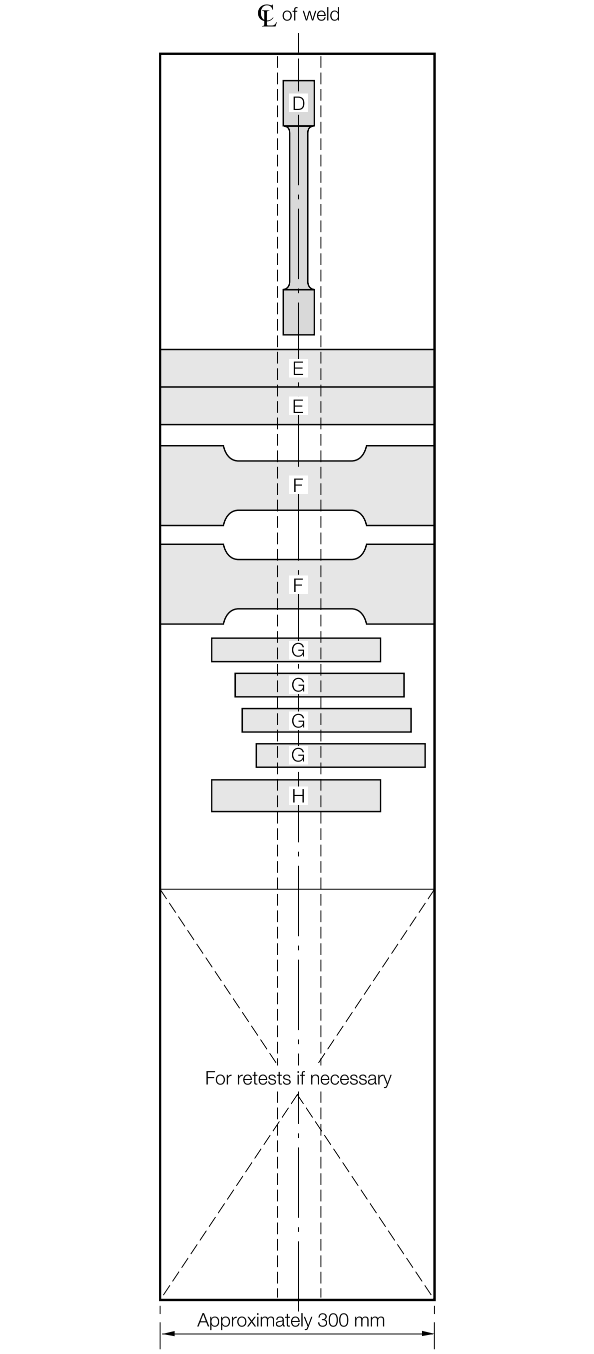


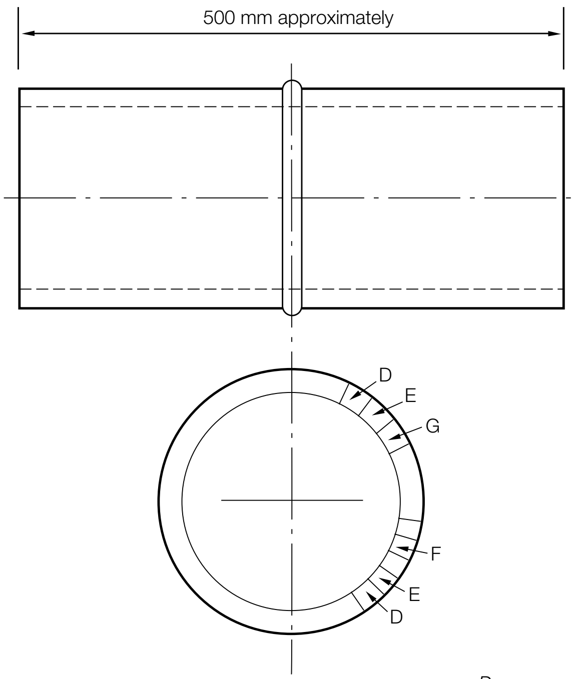
Fig. 13.7.5
Test assembly for T, K and Y connections



Test requirements
A Visual examination
B Surface crack detection
C 100% radiographic examination
D All-weld metal tensile tests (R_e, R_m, A)
E Two bend tests. Two side bends for thickness greater than 20 mm. In other cases one face and one root
F Two transverse tensile tests (R_m)
G Four sets Charpy V-notch impact tests
1 set notched at centre of weld
1set notched at fusion line (FL)
1set notched at FL + 2 mm
1set notched at FL + 5 mm
H One macro specimen including hardness survey

2665/07

Fig. 13.7.6
Butt welds in plate and pipe over 750 mm diameter



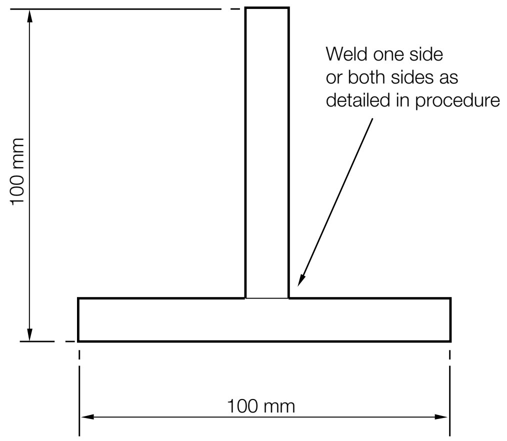
The diameter of the test piece is to be a minimum of $\frac{D}{2}$ where *D* is the maximum diameter of pipe to be welded in construction

Test requirements
A Visual examination
B Surface crack detection
C 100% radiographic examination
D Two transverse tensile tests
E Two bend tests. Two side bends for thickness greater than 20 mm. In other cases one face and one root
F Four sets Charpy V-notch impact tests
1 set notched at centre of weld
1set notched at fusion line (FL)
1set notched at FL + 2 mm
1set notched at FL + 5 mm
G One macro specimen including hardness survey

2665/08

Fig. 13.7.7
Butt welds in pipe less than 750 mm diameter

Approved butt welding procedures will qualify for fillet welds made using the same consumables and welding parameters. Where fillet weld procedures are to be submitted then a test is to be performed as follows:



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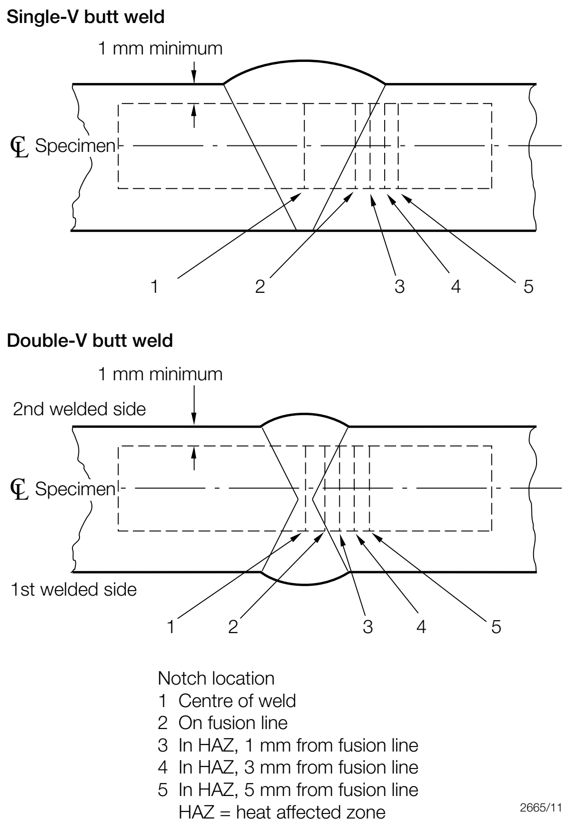
Test requirements
A Magnetic particle examination
B One macro specimen including hardness survey
C Fracture of each fillet through throat

Fig. 13.7.8 Fillet welds



NOTE
The largest size Charpy specimens possible for the material thickness should be machined with the centre of the specimens located as near as practicable to a point midway between the surface and the centre of the thickness. In all cases, the distance from the surface of the material to the edge of the specimen should be approximately 1 mm or greater. In addition to double-V butt welds, specimens should be machined closer to the surface of the second welded side.

Fig. 13.7.9
Orientation of weld test impact specimens

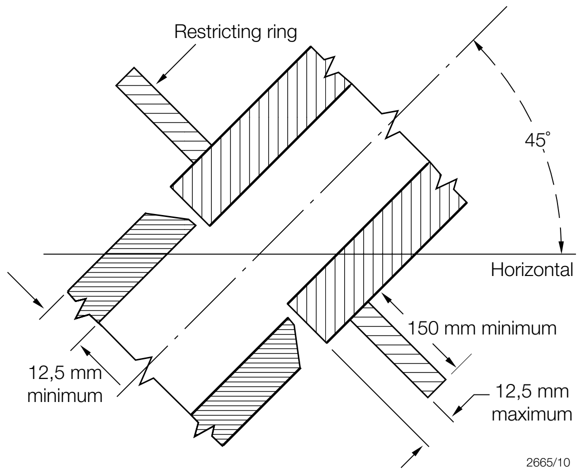


Fig. 13.7.10
Typical test assembly for T, K and Y connections and welds with restricted access

Table 13.7.2 Welder qualification

Types of weld	Test assembly position (*see* Note 1)	Types of weld and welding positions qualified (*see* Note 2)			
		Plate		Pipe	
		Butt	Fillet	Butt	Fillet
Plate/butt	1G 2G 3G (*see* Note 3) 4G 3G and 4G	F F, H F, H, V F, OH F, H, V, OH	F, H F, H F, H, V F, OH F, H, V, OH	F F, H F, H, V	F, H F, H F, H F F, H
Plate/fillet	1F 2F 3F (*see* Note 3) 4F 3F and 4F		F F, H F, H, V F, H, OH F, H, V, OH		F F, H
Pipe/butt	1G rotated 2G 5G 6G 2G and 5G 6GR (*see* Fig. 13.7.10)	F F, H F, V, OH F, H, V, OH F, H, V, OH All (*see* Note 4)	F, H F, H F, V, OH F, H, V, OH F, H, V, OH All	F F, H F, V, OH F, H, V, OH F, H, V, OH All	F, H F, H F, V, OH F, H, V, OH F, H, V, OH All
Pipe/fillet	1F rotated 2F 2F rotated 4F 4F and 5F		F F, H F, H F, H, OH F, H, V, OH		F F, H F, H F, H, OH F, H, V, OH

NOTES
1. Reference should be made to Figs. 13.7.1 to 13.7.4.
2. F = flat; V = vertical; H = horizontal; OH = overhead.
3. Qualification for the 3G and 3F positions is limited to the direction of progression used in the test.
4. Tests in the 6GR position qualify welding in all positions, including T, K and Y welds and welds with restricted access.

Table 13.7.3 Test assembly thickness and range of approval

Thickness, *T*, of plate or wall of pipe	
Test assembly	Range of approval
3 to 10 mm 10 mm min.	3 mm to 2*T* 5 mm and above

Table 13.7.4 Test assembly thickness and range of approval

Pipe diameter, *D*	
Test assembly	Range of approval
25 mm max. 25 to 150 mm 150 mm min.	*D* to 2*D* *D*/2 to 2*D* with 25 mm min. ≥ *D*/2

Table 13.7.5 Welder approval test requirements

Type of weld	Test methods and numbers of specimens		
	Bend	Fracture	Macroexamination
Butt	1 root plus 1 face or 2 side bends		2 (*see* Note)
Fillet		3	2

NOTE
For pipe/butt welds in the GR6 position.

■ *Section 8*
Post weld heat treatment

8.1 Scope

8.1.1 This Section gives the requirements for carrying out post weld heat treatment where it is required, *see* 2.3.4 and 7.3.10.

8.2 Basic requirements for post weld heat treatment

8.2.1 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means of temperature control, and is fitted with pyrometers which will measure and record the temperature of the furnace charge. Sufficient thermocouples are to be connected to the fabrication to show that its temperature is adequately uniform and to enable the temperatures to be recorded throughout the heat treatment.

8.2.2 Details of all heat treatment records, including charts, are to be made available to the Surveyor.

8.2.3 The heat treatment is to consist of heating the fabrication slowly and uniformly to a suitable stress relieving temperature, soaking for a suitable period, followed by cooling slowly and uniformly in the furnace to a temperature not exceeding 400°C and subsequently cooling in a still atmosphere. Details of heating rate and temperature gradient limitations are to be submitted for approval.

8.2.4 The temperature and soaking periods are to be so selected as to relieve residual stress without undue deterioration of the properties of the material. Recommended soaking temperatures are given in Table 13.8.1.

Table 13.8.1 Recommended temperatures for post weld heat treatment

Type of steel	Temperature range °C
Carbon-manganese	580 to 620
Fine grained and low Nickel	580 to 620
$3^1/2$ % Nickel	580 to 600
9% Nickel	560 to 580
12 to 17% chromium martensitic	700 to 790
NOTE For most structural steels the soaking period is to be 2,5 minutes per mm of section thickness, with a minimum of 60 minutes.	

8.2.5 Where fabrications are of such dimensions that the whole length cannot be accommodated in the furnace at one time, the fabrication may be heated in sections, provided that sufficient overlap is allowed to ensure that heat treatment of the entire length of the welds is carried out.

8.3 Test plates

8.3.1 Test plates are to be heat treated in the same furnace and at the same time as the fabrication which they represent.

8.3.2 Alternatively, it may be permissible to heat treat the test plates separately, provided that the Surveyor is satisfied with the means adopted to ensure that the following factors will be the same for the fabrication as for their respective test plates:
(a) rate of heating;
(b) maximum temperature;
(c) time held at maximum temperature; and
(d) conditions of cooling.

8.4 Conditions for omitting post weld heat treatment

8.4.1 Special consideration will be given to proposals to omit post weld heat treatment that would normally be required.

8.4.2 All proposals are to include full details of the application, materials, fabrication and inspection procedures.

8.4.3 Detailed calculations, supported by results of appropriate tests to establish material properties, are to be submitted, demonstrating that, under the most extreme service conditions, with the largest weld flaw which could either exist or remain undetected, the integrity of the structure would not be at risk.

8.4.4 Evidence will be required of the capability of the inspection techniques proposed and of the operators to be used to detect flaws down to the maximum size taken for the calculation in 8.4.3.

■ *Section 9* **Inspection**

9.1 Scope

9.1.1 Inspection is to be carried out in accordance with the manufacturing specification and the non-destructive inspection procedures. This Section provides the minimum requirements with which the latter are to comply.

9.2 General

9.2.1 Effective arrangements are to be provided for the inspection of finished welds to ensure that all welding has been satisfactorily completed. Coatings are not to be applied before final inspection of the welds.

9.2.2 All finished welds are to be sound, uniform, of correct shape and substantially free from slag inclusions, porosity, under-cutting or other defects. Care is to be taken to ensure adequate penetration and fusion; *see* Table 13.9.1 for acceptance levels for defects.

9.2.3 Visual examination of important structural welds is to be supplemented by suitable non-destructive examination. The extent of such examination is to be in accordance with approved plans and with the agreement of LR.

Table 13.9.1 Weld defect acceptance levels for fabrications

Undercut	Slight intermittent undercut is permitted, provided the depth does not exceed 0,5 mm	
Shrinkage grooves/root concavities	Slight intermittent shrinkage grooves, and root concavities permitted to a maximum depth of 1,2 mm	
Excess penetration	3 mm max.	
Misalignment	*t*/5 but 3 mm max.	
Crack (including lamellar tears)	Not permitted	
Lack of root fusion Lack of side-wall fusion Lack of inter-run fusion Lack of root penetration	Not permitted Not permitted Not permitted Slight lack of penetration permitted	
POROSITY Individual pore	 3 mm for *t* up to 50 mm 4,5 mm for *t* over 50 mm and up to 75 mm 6,0 mm for *t* over 75 mm	
Uniformly distributed porosity	2% by area of the weld	
SLAG Individual and parallel to weld axis	 *L* = *t* but 25 mm max. *W* = 1,5 mm max.	
Linear group	Aggregate length not to exceed *t* in a length of 12*t*	
Symbols		
t = plate thickness	*L* = length of defect	*W* = width of defect

NOTES
1. LR is prepared to accept other International and Nationally recognized standards relating to construction, welding and acceptance criteria. Where it is intended to utilize such standards, the acceptance of same should be agreed with LR prior to the commencement of construction.
2. The acceptance levels given in this Table are not necessarily the same as those which might be specified for approval testing of welding procedures.

9.2.4 All defective sections of welds are to be repaired in accordance with the original qualified W.P.S. or, where applicable (e.g. shielded metal arc weld repair of a sub-merged arc weld), by a qualified repair procedure and reinspected. Alternatively, consideration will be given to a documented justification of the acceptability of the defect.

9.2.5 Except where specially agreed by the Surveyors, welds in carbon-manganese or low alloy steels are not to be finally inspected until at least 48 hours after completion of welding of the joint to be inspected. Where post-weld stress relief heat treatment is used, inspection and non-destructive examination can be applied as soon as the structure has cooled to ambient temperature.

9.2.6 Final inspection for acceptance purposes is to be made after final heat treatment where this is required.

9.3 Fabrication tolerances

9.3.1 All fabrication tolerances are to be in accordance with the approved specification. Where appropriate, tolerances are to comply with an International or National Standard.

9.4 Inspection records

9.4.1 Radiographs and other test records of non-destructive examination are to be made available to the Surveyor for assessment.

Plastics Materials

■ *Section 1* General requirements

1.1 Scope

1.1.1 Provision is made in this Chapter for the manufacture and testing of plastics pipes, together with approval requirements for base materials used in the construction or repair of composite vessels, other marine structures, piping and any associated machinery components and fittings which are to be certified or are intended for classification.

1.1.2 These materials and products are to be manufactured and surveyed in accordance with the general requirements of Sections 1, 2 and 3.

1.1.3 For base materials, the manufacturer's works do not require approval by Lloyd's Register (hereinafter referred to as 'LR'), however the Quality Control procedures must be acceptable in accordance with the appropriate Section of this Chapter.

1.1.4 Where a requirement exists for the material to be approved, the test requirements and information to be submitted for approval of polymers, resins, reinforcements and associated materials are defined in Sections 2 and 3.

1.1.5 Specific material requirements relating to the design and manufacture of plastics pipes and fittings are indicated in Section 4, with the material requirements for hull structures contained in Section 5.

1.1.6 For Builders constructing composite vessels, Section 5 provides the minimum material control requirements for acceptance of the works by LR.

1.1.7 For the purposes of these Rules the following definitions apply:

(a) A 'plastics material' is regarded as an organic substance which may be thermosetting or thermoplastic and which, in its finished state, may contain reinforcements or additives.
(b) 'Approved' or 'accepted' refers to materials which hold a valid Certificate, Statement of Acceptance, or Letter of Non-Objection issued by LR.

1.2 Information on material quality and application

1.2.1 Where plastics products are to be classed or certified, the manufacturer is to provide the material producer with such information as is essential to ensure that the base materials to be used are in accordance with the approval requirements and the product specification. This information is to include any survey requirements for the materials.

1.3 Manufacture

1.3.1 Plastics products are to be made at works which have been approved (or accepted) for the type of product being supplied using base materials that have been approved.

1.3.2 Base materials are to be approved in accordance with the requirements of Sections 2 and 3.

1.3.3 In order that a works can be approved (or accepted), the manufacturer is required to demonstrate to the satisfaction of LR that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel. A specified programme of tests is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR. When a manufacturer has more than one works, the approval (or acceptance) is only valid for the individual works which carried out the test programme.

1.4 Survey procedure

1.4.1 The Surveyors are to be allowed access to all relevant parts of the works and are to be provided with the necessary facilities and information to enable them to verify that manufacture is being carried out in accordance with the approved procedure. Facilities are also to be provided for the selection of test material, the witnessing of specified tests and the examination of materials, as required by the Rules.

1.4.2 Prior to the provision of test material for acceptance, manufacturers are to provide the Surveyors with details of the order, specification and any special conditions additional to the Rule requirements.

1.4.3 Before final acceptance, all test materials are to be confirmed as typical of the manufactured product and be submitted to the specified tests and examinations under conditions acceptable to the Surveyors. The results are to comply with the specification and any Rule requirements and are to be to the satisfaction of the Surveyors.

1.4.4 These specified tests and examinations are to be carried out prior to the despatch of finished products from the manufacturer's works.

1.4.5 In the event of any material proving unsatisfactory, during subsequent working, machining or fabrication, it is to be rejected, notwithstanding any previous certification.

1.5 Alternative survey procedure

1.5.1 Where materials are manufactured in quantity by semi-continuous or continuous processes under closely controlled conditions, an alternative system for testing and inspection may be adopted, subject to the agreement of the Surveyors.

1.5.2 In order to be considered for approval, manufacturers are to comply with the requirements of Ch 1,2.

1.6 Post-cure heating

1.6.1 Post-cure heating is to be carried out in properly constructed ovens which are efficiently maintained and have adequate means for control and recording of temperature. The oven is to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components which require post-cure heating, alternative methods will be specially considered.

1.7 Test material

1.7.1 Sufficient material is to be provided for the preparation of the test specimens detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

1.7.2 Where test materials, (either base materials or product sample materials) are selected by the Surveyor or a person nominated by LR, these are to be suitably identified by markings which are to be maintained during the preparation of the test specimens.

1.7.3 All base material samples for testing are to be prepared under conditions that are as close as possible to those under which the product is to be manufactured. Where this is not possible, a suitable procedure is to be agreed with the Surveyor.

1.7.4 During production, check test samples are to be provided as requested by the Surveyor.

1.7.5 Should the taking of these samples prove impossible, model samples are to be prepared concurrently with production. The procedure for the preparation of these samples is to be agreed with the Surveyor.

1.7.6 The dimensions, number and orientation of test specimens are to be in accordance with the requirements of a National or International Standard acceptable to LR.

1.8 Re-test procedure

1.8.1 Where test material fails to meet the specified requirement, two additional tests of the same type may be made at the discretion of the Surveyor.

1.8.2 Where an individual test result in a group (minimum five) deviates from the mean by more than two standard deviations in either the higher or lower direction, the result is to be excluded and a re-test made. Excluded results of tests are to be reported with confirmation that they have been excluded. Only one exclusion is acceptable in any group of tests.

1.9 Visual and non-destructive examination

1.9.1 Prior to the final acceptance, surface inspection, verification of dimensions and non-destructive examination are to be carried out in accordance with the requirements detailed in Sections 3, 4 and 5 of this Chapter.

1.9.2 When there is visible evidence to doubt the soundness of any material or component, such as flaws or suspicious surface marks, it is to be the responsibility of the manufacturer to prove the quality of the material by any suitable method.

1.10 Rectification of defective material

1.10.1 Small surface blemishes may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from structural defects and the rectification has been completed to the satisfaction of the Surveyor.

1.10.2 Repair procedures for larger defects are to be agreed with LR prior to implementation.

1.11 Identification of products and base materials

1.11.1 The manufacturer of approved materials is to identify each batch with a unique number.

1.11.2 The manufacturer of plastics products is to adopt a system of identification which will enable all finished products to be traced to the original batches of base materials. Surveyors are to be given full facilities for tracing any component or material when required.

1.11.3 When any item has been identified by the personal mark of a Surveyor, or deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

1.11.4 Before any pipe or fitting is finally accepted it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements as given in Section 4.

1.11.5 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

1.12 Certification

1.12.1 Certification of the finished product is to be in accordance with the requirements of the appropriate Sections.

■ *Section 2* Tests on polymers, resins, reinforcements and associated materials

2.1 Scope

2.1.1 This Section gives the tests and data required by LR for materials approval and/or inspection purposes on the following:
(a) Thermoplastic polymers.
(b) Thermosetting resins.
(c) Reinforcements.
(d) Reinforced thermoplastic polymers.
(e) Reinforced thermosetting resins.
(f) Core materials.
  (i) End-grain balsa.
  (ii) Rigid foams.
  (iii) Synthetic felt type materials.
(g) Machinery chocking compounds.
(h) Rudder and pintle bearings.
(j) Stern tube bearings.
(k) Plywoods.
(l) Adhesive and sealant materials.
(m) Repair compounds.

2.2 Thermoplastic polymers

2.2.1 The following data is to be provided by the manufacturer for each thermoplastic polymer:
(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Bulk density.
(e) Filler content, where applicable.
(f) Pigment content, where applicable.
(g) Colour.

2.2.2 Samples for testing are to be prepared by moulding or extrusion under the polymer manufacturer's recommended conditions.

2.2.3 The following tests are to be carried out on these samples:
(a) Tensile stress at yield and break.
(b) Modulus of elasticity in tension.
(c) Tensile strain at yield and break.
(d) Compressive stress at yield and break.
(e) Compressive modulus.
(f) Temperature of deflection under load.
(g) Determination of water absorption.

2.3 Thermosetting resins

2.3.1 The data listed in Table 14.2.1 is to be provided by the manufacturer for each thermosetting resin.

Table 14.2.1 Data requirements for thermosetting resins

Data	Type of resin		
	Polyester (*see* Note 3 for vinylester)	Epoxide	Phenolic
Specific gravity of liquid resin	required	required	required
Viscosity	required	required	required
Gel time	required	required	not applicable
Appearance	required	required	required
Mineral content (*see* Note 1)	required	required	not applicable (*see* Note 2)
Volatile content	required	not applicable	not applicable
Acid value	required	not applicable	not applicable
Epoxide content	not applicable	required	not applicable
Free phenol	not applicable	not applicable	required
Free formaldehyde	not applicable	not applicable	required

NOTES
1. This is to be the total filler in the system, including thixotrope, filler, pigments, etc., and is to be expressed in parts by weight per hundred parts of pure resin.
2. If the resin is pre-filled, the mineral content is required.
3. Vinylesters are to be treated as equivalent to polyesters.

2.3.2 Cast samples are to be prepared in accordance with the manufacturer's recommendations and are to be cured and post-cured in a manner consistent with the intended use. The curing system used and the ratio of curing agent (or catalyst) to resin are to be recorded. Where post-cure conditions equivalent to ambient-cure conditions apply, *see* 3.2.2 and 3.2.3.

2.3.3 The following are to be determined using these samples:
(a) Tensile strength (stress at maximum load) and stress at break.
(b) Tensile strain at maximum load.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Temperature of deflection under load.
(e) Barcol hardness.
(f) Determination of water absorption.
(g) Volume shrinkage after cure.
(h) Specific gravity of cast resin.

2.3.4 In addition, for gel coat resins the stress at break and modulus of elasticity in flexure are to be determined.

2.4 Reinforcements

2.4.1 The following data is to be provided, where applicable, for each type of reinforcement:

(a) Reinforcement type.
(b) Fibre type for each direction.
(c) Fibre tex value.
(d) Fibre finish and/or treatment.
(e) Yarn count in each direction.
(f) Width of manufactured reinforcement.
(g) Weight per unit area of manufactured reinforcement.
(h) Weight per linear metre of manufactured reinforcement.
(j) Compatibility (e.g. suitable for polyesters, epoxides, etc.).
(k) Constructional stitching – details of yarn, specific gravity, type, frequency and direction.
(l) Weave type.
(m) Binder type and content.
(n) Density of the fibre material.

2.4.2 Tests of the mechanical properties are to be made on laminate samples containing the reinforcement and prepared as follows:

(a) an approved resin of suitable type is to be used;
(b) a minimum of three layers of the reinforcement is to be laid with parallel ply to give a laminate not less than 4 mm thick;
(c) the weights of resin and reinforcement used are to be recorded together with the measured thickness of the laminate, including the measured weight per unit area of the reinforcement used;
(d) for glass reinforcements, the glass/resin ratios, by weight, as shown in Table 14.2.2 are to be used;
(e) for reinforcement type other than glass, a fibre volume fraction, as shown in Table 14.2.3, is to be used.

Table 14.2.2 Glass fraction by weight for different reinforcement types

Reinforcement type	Glass fraction nominal values
Unidirectional	0,60
Chopped strand mat	0,30
Woven roving	0,50
Woven cloth	0,50
Composite roving (*see* Note)	0,45
Gun rovings	0,33
±45° stitched parallel plied roving	0,50
Triaxial parallel plied roving	0,50
Quadriaxial parallel plied roving	0,50

NOTE
Continuous fibre reinforcement with attached chopped strand mat.

2.4.3 Rovings intended for filament winding are to be tested as unidirectional rovings.

Table 14.2.3 Content by volume for different reinforcement types

Reinforcement type	Content by volume nominal values
Unidirectional	0,41
Chopped strand mat	0,17
Woven roving	0,32
Woven cloth	0,32
Composite roving (*see* Note)	0,28
Gun rovings	0,19
±45° stitched parallel plied roving	0,32
Triaxial parallel plied roving	0,32
Quadriaxial parallel plied roving	0,32

NOTE
The volume content may be converted to weight fractions by use of the formula:

$$W_F = V_F D_F/(D_F V_F + D_R V_R)$$

where
W_F = fibre fraction by weight
D_F = density of fibre
D_R = density of cured resin
V_F = fibre fraction by volume
V_R = resin fraction by volume

2.4.4 The following tests as defined in Section 3 are to be made on the samples:

(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Apparent interlaminar shear.
(j) Fibre content.
(k) Determination of water absorption.

2.4.5 The laminate is to be tested in air in the directions indicated by Table 14.2.4.

Table 14.2.4 Fibre orientations in reinforced test specimens

Type of reinforcement	Test orientations
Unidirectional	0°
Chopped strand mat Gun roving	any direction
Woven roving Woven cloth Composite roving	0° and 90°
± 45° parallel plied roving Triaxial plied roving Quadriaxial plied roving	0°, 45°, 90° and –45°

2.4.6 Additionally, tests in 2.4.4(c) and (f) are to be repeated, in one direction only, after immersion in fresh water at 35°C for 28 days with the exception of 2.4.4(k).

2.5 Reinforced thermoplastic polymers

2.5.1 Thermoplastic polymers intended for use with reinforcements are to be tested in accordance with 2.2.1 to 2.2.3.

2.5.2 A laminate is to be prepared using the polymer and an approved reinforcement in accordance with a manufacturing specification. The laminate is to be tested in accordance with the appropriate requirements of 2.4.4. Testing may be confined to one direction only.

2.6 Reinforced thermosetting resins

2.6.1 Thermosetting resins intended for use with reinforcements are to be tested in accordance with 2.3.1 to 2.3.4.

2.6.2 No further tests are required for gel coat resins.

2.6.3 For laminating resins, a laminate is to be prepared using the resin and an approved reinforcement as follows:
(a) For polyester resins, chopped strand mat.
(b) For epoxide resins, a balanced woven roving.
(c) For phenolic resins, a balanced woven material.

2.6.4 The laminate is to be tested in accordance with 2.4.4 in one fibre direction only.

2.7 Core materials

2.7.1 **General requirements**. The following data is to be provided for each type of core material:
(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.
(f) Surface treatment.

2.7.2 Manufacturers are required to provide a full application procedure for use of the product.

2.8 Specific requirements for end-grain balsa

2.8.1 The supplier is to provide a signed statement that the balsa (ochroma lozopus) is cut to end-grain, is of good quality, being free from unsound or loose knots, holes, splits, rot, pith and corcho, and that it has been treated against fungal and insect attack, shortly after felling, followed by homogenization, sterilization and kiln drying to an average moisture content of no more than 12 per cent.

2.8.2 The following tests are to be carried out on the virgin material, both parallel to and perpendicular to the grain:
(a) Compressive strength (stress at maximum load).
(b) Compressive modulus of elasticity.
(c) Tensile strength (stress at maximum load).
The density of the virgin material is also to be tested.

2.8.3 Where the balsa is mounted on a carrier material (e.g. scrim), any adhesive used is to be of a type compatible with the proposed resin system.

2.8.4 Core shear properties are to be determined according to the requirements of 3.8.1.

2.9 Specific requirements for rigid foams (PVC, Polyurethane and other types)

2.9.1 The foam is to be of the closed cell type and compatible with the proposed resin system (e.g. polyester, epoxide, etc.).

2.9.2 Foams are to be of uniform cell structure.

2.9.3 Data is to be provided on the dimensional stability of the foam by measurement of the shrinkage.

2.9.4 The following test data is to be submitted for each type of foam:
(a) Density.
(b) Tensile strength (stress at maximum load).
(c) Tensile modulus of elasticity.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus of elasticity.

2.9.5 Core shear properties are to be determined according to the requirements of 3.8.1.

2.9.6 Additionally, the compressive properties (*see* 2.9.4(d) and (e)) are to be determined at a minimum of five points over the temperature range ambient to maximum recommended service or 70°C, whichever is the greater.

2.10 Synthetic felt type materials with or without microspheres

2.10.1 For materials of this type, the following data is required in addition to the requirements of 2.7.1:
(a) Fibre type.
(b) Width.
(c) Width of finished material.
(d) Weight per unit area of the manufactured material.
(e) Weight per linear metre of the manufactured material.
(f) Compatibility.
(g) Details of the method of combining.

2.10.2 A laminate of the material is to be prepared using a suitable approved resin under conditions recommended by the manufacturer.

2.10.3 The following properties are to be determined:
(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Modulus of elasticity in tension or secant modulus at 0,25 per cent and 0,5 per cent strain.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Fibre content.
(j) Water absorption.

2.10.4 In the case of anisotropic materials (e.g. where combined with other reinforcements) the tests listed in 2.10.3 are to be conducted in the 0°, 90° directions and in any other reinforcement direction.

2.10.5 Additionally, the tests listed in 2.10.3 are to be repeated after immersion in fresh water at 35°C for 28 days. For anisotropic materials, the requirement is for this test to be carried out in one direction only.

2.10.6 The shear properties (of the resin filled system) are to be determined according to 3.8.1.

2.11 Machinery chocking compounds (resin chocks)

2.11.1 Thermosetting materials for filling the space between the base of machinery and its foundation where the maintenance of accurate alignment is necessary are to be approved by LR before use.

2.11.2 Approval will be considered by LR for use under the following service conditions:
- Loading of 2,5 N/mm^2 (max) for a temperature not exceeding 60°C.
- Loading of 3,5 N/mm^2 (max) for a temperature not exceeding 80°C.
- Other loading conditions.

2.11.3 The exotherm temperature, defined as the maximum temperature achieved by the reacting resin under conditions equivalent to those of intended use, is to be determined according to a procedure approved by LR.

2.11.4 The following properties are to be determined on chock material cured at the measured exotherm temperature:
(a) The impact resistance (Izod).
(b) Hardness.
(c) Compressive strength (stress at maximum load) and modulus of elasticity.
(d) Water absorption.
(e) Oil absorption.
(f) Heat deflection temperature.
(g) Compressive creep is to be measured according to 3.9.4.
(h) Curing linear shrinkage.
(j) Flammability.

2.11.5 The chocking compound approval is contingent on the material achieving the minimum exotherm value as specified when used on an installation under practical conditions.

2.11.6 Where the resin chock is to be used for installation of sterntubes and sternbushes in addition to the requirements of 2.11.4, the tensile strength and modulus of elasticity in tension are to be measured.

2.11.7 The manufacturer's installation procedure is required to be documented and is to be to the satisfaction of LR.

2.12 Rudder and pintle bearings

2.12.1 Materials used for rudder and pintle bearings are to be approved by LR before use.

2.12.2 Initial approval is to be based on a review of the following physical properties of the material:
(a) Compressive strength (stress at maximum load) and modulus of elasticity.
(b) Tensile strength (stress at maximum load) and modulus of elasticity.
(c) Shear strength (stress at maximum load).
(d) Impact strength.
(e) Swelling in oil and in water.
(f) Hardness.

2.12.3 Additionally, friction data is to be provided under both wet and dry conditions.

2.12.4 Furthermore, the installation instructions (especially recommended clearances) are to be reviewed by LR prior to provisional approval being given.

2.12.5 If the above data is satisfactory, the material will be provisionally approved until sufficient service experience has been gained.

2.13 Sterntube bearings

2.13.1 Materials used for sterntube bearings are to be approved by LR before use.

2.13.2 Approval is to be based on a review of the physical properties as given by 2.12.2.

2.13.3 Friction data is to be provided under the lubrication system(s) proposed for the material(s).

2.14 Plywoods

2.14.1 All plywoods are to be approved to BS 1088 or equivalent National or International Standard in accordance with LR's Type Approval Procedure.

2.14.2 For structural applications in the marine environment, a minimum timber rating of moderate durability according to BS 1088 is required.

2.14.3 Enhancement of durability by use of preservatives is permitted, subject to each veneer layer being treated with a recognized preservative.

2.14.4 Where Okoume, as specified by BS 1088 is involved, (i.e. non-durable timber classification) this may only be used for marine structures subject to the specific application being acceptable to LR.

2.15 Adhesive and sealant materials

2.15.1 Materials of these types are to be accepted by LR before use.

2.15.2 The requirements for acceptance are dependent on the nature of the application.

2.15.3 In the first instance, the manufacturer is to submit full details of the product, procedure for method of use (including surface preparation) and the intended application. After review of these details, LR will provide a specific test schedule for confirmation of the material's properties.

2.15.4 Any acceptance granted will be limited to specific applications and will be contingent on the instructions for use being adhered to.

2.16 Repair compounds

2.16.1 Materials used for repairs are to be accepted by LR before use.

2.16.2 For acceptance purposes, the manufacturer is to submit full product details, and user instructions, listing the types of repair for which the system is to be used together with details of any installer accreditation schemes.

2.16.3 Dependent on the proposed uses, LR may require testing in accordance with a specified test programme.

2.16.4 Materials will not be accepted for the following uses unless specific evidence of their suitability is provided:

(a) Any component in rubbing contact.
(b) Any component subject to dynamic cyclic loading.
(c) Any pressure part in contact with gas or vapour.
(d) Any pressure part in contact with liquid above 3,5 bar.
(e) Any component where operating temperature exceeds 90°C.

All uses of materials of these types are subject to the discretion of the Surveyor.

■ *Section 3* Testing procedures

3.1 General

3.1.1 This Section gives details of the test methods to be used for base materials and on finished plastics products such as fibre reinforced plastics (FRP) piping and any testing required in the construction of composite vessels.

3.1.2 In general, testing is to be carried out by a competent independent test house which, at the discretion of LR, may or may not require witnessing by the Surveyor.

3.1.3 Alternatively, testing may be carried out by the manufacturer subject to these tests being witnessed by the Surveyor.

3.1.4 All testing is to be carried out by competent personnel.

3.1.5 Unless specified otherwise, testing is to be carried out in accordance with a recognized ISO Standard, where one exists, and all test programmes are to have written procedures.

3.1.6 Alternatively, testing may be carried out in accordance with a National Standard provided that it conforms closely to an appropriate ISO standard and subject to prior agreement with the Surveyor.

3.1.7 Mechanical properties are to be established using suitable testing machines of approved types. The machines and other test equipment are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. Calibration is to be undertaken by a nationally recognized authority or other organization of standing and is to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house. The accuracy of test machines is to be within ± one per cent.

3.2 Preparation of test samples

3.2.1 Thermoplastic samples are to be prepared in accordance with the manufacturer's recommendations for moulding. For finished products, samples are to be taken from the product during production in accordance with the manufacturer's quality plan, but where this is impractical, separate test samples are to be prepared in a manner identical with that of the product.

3.2.2 Samples of thermosetting resins are to be prepared using the curing system recommended by the manufacturer and identical with that used for the finished product.

3.2.3 The post curing conditions for samples of thermosetting resins are to be as recommended by the manufacturer and identical with those used for the finished product. Where the samples are made for the general approval of a resin, the post curing conditions are to be those in which the resin is intended to be used.

3.2.4 Where curing of the product is intended to take place at room temperature, the sample is to be allowed to cure at room temperature (18 to 21°C) for 24 hours followed by a post-cure at 40°C for 16 hours.

3.2.5 Where a reinforcement is to be used, the ratio of reinforcement to resin or polymer is to be nominally the same as that of the finished product or in accordance with Table 14.2.2 or 14.2.3.

3.2.6 Where laminates are prepared specifically for approval test purposes, the reinforcement is to be laid parallel plied.

3.3 Preparation of test specimens

3.3.1 The test specimen is to be prepared in accordance with the appropriate ISO standard and the requirements of this Section.

3.3.2 Precautions are to be taken during machining to ensure that the temperature rise in the specimen is kept to a minimum.

3.4 Testing

3.4.1 Strain measurement is to be made by the use of a suitable extensometer or strain gauge.

3.4.2 The rate of strain is to be in accordance with the appropriate ISO standard.

3.4.3 The number of test specimens from each sample to be tested is to be in accordance with the ISO standard. For mechanical testing this is five.

3.5 Discarding of test specimens

3.5.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine, it is to be discarded and replaced by a new specimen.

3.5.2 In addition, if the deviation of one result in a group of five exceeds the mean by more than two standard deviations, that result is to be discarded and one further specimen tested, *see* 1.8.1 and 1.8.2.

3.6 Reporting of results

3.6.1 All load/displacement graphs and tabulated results are to be reported, including mean values and the calculated standard deviation.

3.6.2 Additionally, full details of the sample and specimen preparation are to be provided including (where applicable):
(a) Catalyst/accelerator or curing agent types and mix ratio.
(b) Weights of resins, and/or reinforcements used.
(c) Casting/laminate dimensions.
(d) Number of layers of reinforcement used.
(e) Curing/post-curing conditions.

3.7 Tests for specific materials

3.7.1 The data requirements in 2.2 and 2.3 for thermoplastic or thermosetting resins or polymers are to be determined in accordance with suitable National or International Standards.

3.7.2 Recognized Standards to which specimens of unreinforced thermoplastic resins are to be tested are listed in Table 14.3.1.

Table 14.3.1 Tests for unreinforced thermoplastic resins

Test	Standard	
Tensile properties	ISO 527-2	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62	Method 1
Temperature of deflection under load	ISO 75-2	Method A
Compressive properties	ISO 604	Test speed – as for ductile materials

NOTES
1. Water absorption – result to be expressed as milligrams.
2. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

3.7.3 Test standards for unreinforced cast thermosetting resins are given in Table 14.3.2.

Table 14.3.2 Tests on unreinforced cast thermoset resin specimens

Test	Standard	
Tensile properties	ISO 527-2	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62	Method 1
Temperature of deflection under load	ISO 75-2	Method A
Compressive properties	ISO 604	Test speed = 1 mm/min

NOTES
1. ISO 62 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-2 – tensile properties are to be measured using extensometry.

3.7.4 The Standards to which laminate specimens of any type are to be tested are listed in Table 14.3.3.

Table 14.3.3 Tests on laminate specimens

Test	Standard	
Tensile properties	ISO 527-4	Test speed = 2 mm/min Specimens Types II or III
Flexural properties	ISO 14125	Test speed = $\frac{\text{Thickness}}{2}$ mm/min Method A
Compressive properties	ISO 604	Test speed = 1 mm/min
Interlaminar shear	ISO 14130	
Water absorption	ISO 62	Method 1
Glass content	ISO 1172	

NOTES
1. ISO 62 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-4 – tensile properties are to be measured using extensometry.
3. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

3.8 Structural core materials

3.8.1 Initially, the core shear strength and modulus are to be determined by ISO 1922–1981 or ASTM C273. Test sandwich panels are then to be prepared and subjected to four-point flexural tests to determine the apparent shear properties according to ASTM C393 (short beam) at two representative thicknesses (i.e. 15 mm and 30 mm). Testing is to be carried out at ambient temperature and at 70°C. The following requirements are to be observed:

(a) Each skin is to be identical and have a thickness not greater than 21 per cent of the nominal core thickness. For hand laid constructions, each skin is to comprise a lightweight chopped strand mat reinforcement (300 g/m^2) consolidated at a glass content, by weight, of 0,3 against the core, plus the required number of woven reinforcements consolidated, using an isophthalic polyester resin, to give a minimum glass content, by weight, of 0,5.

(b) The method of construction of the sandwich laminate is to reflect the core material manufacturer's instructions for use, i.e. application of bonding paste, surface primer or any other recommended system.

(c) Where vacuum bagging techniques or equivalent systems are used, these will be subject to individual consideration.

(d) All resins and reinforcements are to hold current LR approval.

(e) Curing conditions are to be in accordance with 3.2.3 and 3.2.4.

(f) The dimensions of the test samples should be based on the requirements of ASTM C393 Paragraph 5.1, and the ratio parameters as indicated in ASTM C393 Paragraph 5.2, using a proportional limit stress (F) for the woven roving skins of 130 N/mm^2 and a span (a_2) of not less than 400 mm.

3.8.2 For each type of test sample, the following data are to be reported, together with the submission of a representative test sample showing the mode of failure for each density of core material:

(a) Skin and core thickness, and core type and density.

(b) Resin/catalyst/accelerator ratio.

(c) Skin construction, including types and weight of reinforcements, resin(s), etc.

(d) Details of production method and curing conditions (temperature and times).

(e) Where additional preparation of the foam is involved, for example the use of primers or bonding pastes, full details are to be provided.

(f) Actual span between base supports for each type of test sample.

3.8.3 The following requirements apply to end-grain balsa:

(a) The data requirements of 2.7.1 are to be provided, where applicable, according to suitable National or International Standards.

(b) The balsa is to be tested according to the requirements of 3.8.1.

(c) The test methods for balsa are given in Table 14.3.4.

Table 14.3.4 Tests on end-grain balsa

Test	Standard
Density	ISO 845-1977
Tensile properties	ASTM C297-61 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Compressive properties	ISO 844-1978 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Shear properties	ISO 1922-1981 Test speed = 1mm/min

3.8.4 The following requirements apply to rigid foams:

(a) The data requirements of 2.7.1 are to be provided in accordance with a suitable National or International Standard.

(b) The foam is to be tested according to the requirements of 3.8.1.

(c) The test methods for rigid foams are to be in accordance with Table 14.3.4.

3.8.5 The following requirements apply to synthetic felt type materials:

(a) The data requirements of 2.10.1 are to be provided according to suitable National or International Standards.

(b) The material is to be tested according to the requirements of 3.8.1, with the following modifications:
   (i) The core of the laminate test sandwich panel is to be prepared with a fibre content as recommended by the manufacturer.
   (ii) The felt fibre/resin ratio is to be stated.
   (iii) The required test thicknesses of the cores are to be changed from 30 mm and 15 mm to 12 mm and 6 mm respectively.

(c) The prepared laminate of the base material is to be of minimum thickness 3,5 mm with a minimum of three layers.

(d) The specified tests on the laminate (*see* 2.10.3) are to be conducted according to the requirements of Table 14.3.3.

3.9 Machinery chocking compounds

3.9.1 Test samples of the cured chock resin are to be prepared under ambient conditions and then post-cured at the exotherm temperature as determined in 2.11.3.

3.9.2 The specified properties are to be determined as required by Table 14.3.5.

Table 14.3.5 Tests for machinery chocking compounds

Test	Standard
Izod Impact Resistance	ISO 180-1993 Unnotched
Barcol hardness	EN 59
Compressive strength	ISO 604 Test speed = 1 mm/min
Water absorption	ISO 62 Method 1 25 mm x 20 mm cylinder (to constant weight)
Oil absorption (light machine)	ISO 175 25 mm x 20 mm cylinder (to constant weight)
Temperature of deflection under load	ISO 75-2 Method A

3.9.3 The percentage linear shrinkage of cured material is to be measured.

3.9.4 Creep is to be measured according to the following method:

(a) A 25 mm x 20 mm diameter parallel faced cylinder is to be pre-loaded against a steel base at 2,5 N/mm^2 or 3,5 N/mm^2, or at the specified higher loading condition, at ambient temperature for 16 hours.

(b) The temperature is to be increased at the rate of 8°C per hour until the service temperature (60°C or 80°C) is reached.

(c) During this time, the creep of the cylinder is to be measured at 15 minute intervals.

(d) The temperature and loading are to be maintained for a minimum of 100 days measuring the creep at intervals of 24 hours.

(e) A plot of creep in mm (linear scale) against time (log scale), together with full experimental details, is to be provided for review by LR.

3.10 Rudder and pintle bearings

3.10.1 All mechanical properties as required by 2.12 are to be measured according to suitable National or International Standards.

3.10.2 Frictional properties are to be determined according to a method agreed with LR.

3.11 Sterntube bearings

3.11.1 The requirements for sterntube bearings are as defined in 2.13.

■ *Section 4*
Plastics pipes and fittings

4.1 Scope

4.1.1 This Section gives the general requirements for plastics pipes and fittings, with or without reinforcement, intended for use in the services listed in the relevant Rules dealing with design and construction. Hoses and mechanical couplings are not covered by these requirements.

4.1.2 Pipes and fittings intended for application in Class I, Class II and Class III systems for which there are Rule requirements, are to be manufactured in accordance with the requirements of Section 1 and this Section.

4.1.3 As an alternative to 4.1.2, plastics pipes and fittings which comply with National or proprietary specifications may be accepted, provided that the specifications give reasonable equivalence to the requirements of this Section or, alternatively, are approved for a specific application. The survey and certification are however to be carried out in accordance with the requirements of this Section.

4.2 Design requirements

4.2.1 The requirements for design approval are detailed in the relevant Rules.

4.2.2 The design submission is to include a materials list with confirmation that the materials listed have properties and characteristics conforming with those values used in the design submission. As a minimum, the details given should include the following:

(a) Resin.
(b) Accelerator (type and concentration).
(c) Catalyst or curing agent (type and concentration).
(d) Reinforcement.
(e) Cure/post-cure conditions.
(f) Resin/reinforcement ratio.
(g) Wind angle (or lay-up sequence) and orientation.
(h) Dimensions and tolerances.

This submission is to include similar details for the fittings together with a description of the method of attachment of the fittings to the pipes.

4.2.3 Any alteration of the component materials or manufacturing operations from those used in the design submission will necessitate a completely new submission.

4.2.4 If the piping manufacturer anticipates the possible use of alternative materials, these should be listed in the design submission. Proof that the modified product will meet the specified requirements will be needed prior to its use.

4.3 Manufacture

4.3.1 Plastics pipes and fittings intended for use in Class I, Class II and Class III systems are to be manufactured at facilities approved by LR, using materials approved by LR.

4.3.2 A Manufacturing Specification is to be submitted. This is to contain details of the following:

(a) All constituent materials.
(b) Manufacturing procedures such as lay-up sequence or wind angle, the ratios of curing agent to resin and reinforcement to resin, the laminate thickness, the mandrel dwell time (initial cure) and the cure and post-cure conditions.
(c) Quality control procedures including details and frequency of tests on the incoming materials, tests made during production and on the finished piping.
(d) Acceptance standards and tolerances, including all dimensions.
(e) Procedures for cosmetic repair.
(f) System for traceability of the finished piping to the batches of raw materials.
(g) Method of bonding pipes and fittings.

4.3.3 Details of all raw materials are to be submitted for approval and are to be in accordance with the Manufacturing Specification and the design submission.

4.3.4 All batches of raw materials are to be provided with unique identifications by their manufacturers.

4.3.5 No batch of material is to be used later than its date of expiry.

4.3.6 The piping manufacturer is to ensure that all batches of materials are used sequentially.

4.3.7 The piping manufacturer is to maintain records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the Manufacturing Specification.

4.3.8 Records are to be kept of the wind angle and/or the orientation of the reinforcement.

4.3.9 The piping manufacturer is to ensure that each item of piping is traceable to the batch or batches of material used in its manufacture. The unique identifications referred to in 4.3.4 are to be included on all documents.

4.3.10 The curing oven is to be suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

4.3.11 The temperature of the pipe or fitting is to be controlled and recorded by the attachment of suitably placed thermocouples.

4.4 Quality assurance

4.4.1 The piping manufacturer is to have a quality assurance system approved to ISO 9001 or equivalent. This system should ensure that the pipes and fittings are produced with uniform and consistent mechanical and physical properties in accordance with acceptable standards.

4.5 Dimensional tolerances

4.5.1 Dimensions and tolerances are to conform to the Manufacturing Specification.

4.5.2 The wall thicknesses of the pipes are to be measured at intervals around the circumference and along the length in accordance with an appropriate National Standard. The thicknesses are to accord with the Manufacturing Specification.

4.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

4.6 Composition

4.6.1 The composition of the pipes and fittings is to be in accordance with the Manufacturing Specification.

4.6.2 Where alternative materials are used (*see* 4.2.4), the manufacturer is to demonstrate to the Surveyor's satisfaction, and prior to their introduction, their suitability with respect to the performance of the piping. Otherwise, full testing as specified in 4.7 will be required.

4.7 Testing

4.7.1 For thermoplastic pipes, the polymer manufacturer is to make the following measurements on samples taken from each batch:

(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

4.7.2 The values obtained are to be certified by the polymer manufacturer.

4.7.3 For reinforced thermoset pipes,the resin manufacturer is to determine, on samples taken from each batch, at least the following:

(a) All resins:
  (i) Viscosity.
  (ii) Gel time.
  (iii) Filler content, where applicable.
(b) Polyester resins:
  (i) Type (orthophthalic, isophthalic, etc.).
  (ii) Volatiles content.
  (iii) Acid value.
(c) Epoxide resins:
  (i) Free epoxide content.
(d) Phenolic resins:
  (i) Free phenol content.
  (ii) Free formaldehyde content.

4.7.4 The values obtained are to comply with the requirements of the Manufacturing Specification.

4.7.5 Where the resin manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 4.7.1 to 4.7.3 as appropriate. The mixed batch is then to be given a unique batch number.

4.7.6 The polymer or resin manufacturer is to demonstrate that each batch of polymer or resin satisfies the requirement for temperature of deflection under load and this is not to be less than 80°C.

4.7.7 These measurements should be repeated on each batch by the piping manufacturer. Where this is not done, LR may require that the tests be made on a random basis by an independent laboratory.

4.7.8 The piping manufacturer is to confirm, by means of tests on at least one batch in twenty, that the temperature of deflection under load exceeds the specified minimum under manufacturing conditions.

4.7.9 Where reinforcements are used, at least the following are to be recorded, where applicable:

(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

4.7.10 All items in 4.7.9 are to comply with the Manufacturing Specification.

4.7.11 The piping manufacturer is to maintain accurate records of resin and glass usage and is to calculate the resin/glass ratio on an ongoing basis.

4.7.12 During manufacture of the piping, apart from the requirements of 4.7.5, 4.7.6 and 4.7.8, tests are to be carried out on the constituents and final product in accordance with Table 14.4.1.

Table 14.4.1 Testing during manufacture of pipes

Component/ operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time Rate of consumption	Two per shift Continuous
Reinforcement	Quality Wind angle Rate of consumption	Continuous Continuous Continuous
Resin/ reinforcement	Ratio	Continuous
Pipe	Post-cure: temperature of the pipe in oven Cure level Dimensions Hydraulic pressure test Electrical resistance Hydraulic bursting test Axial strength	Continuous At least eight per length Each length Each length Each length (*see* Note) At Surveyor's discretion At Surveyor's discretion

NOTE
Measurements of electrical resistance are only required on piping where the operating conditions given in Pt 5, Ch 12,5.2.4 apply.

4.7.13 The standards of acceptance are those listed in the Manufacturing Specification approved by LR.

4.7.14 At the Surveyor's discretion, sections of pipe are to be subjected to hydraulic bursting tests and/or measurements of axial strength.

4.7.15 If the batch of resin or polymer, or the curing agent, or their ratio is changed during manufacture of a batch of pipes, at least two additional measurements of the gel time are to be carried out during each shift.

4.8 Visual examination

4.8.1 All pipes and fittings are to be visually examined and are to be free from surface defects and blemishes.

4.8.2 The pipes are to be reasonably straight and the cut ends are to be square to the axis of the pipe.

4.9 Hydraulic test

4.9.1 Each length of pipe is to be tested at a hydrostatic pressure not less than 1,5 times the rated pressure of the pipe.

4.9.2 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test, endorsed by the Surveyor, will be accepted.

4.10 Repair procedure

4.10.1 Repairs are not allowed, with the exception of minor cosmetic blemishes as detailed in 1.10.1.

4.10.2 A repair procedure for these minor blemishes is to be included in the Manufacturing Specification.

4.11 Identification

4.11.1 All piping is to be identified in such a manner that traceability to all the component materials used in its manufacture is ensured. The Surveyor is to be given full facilities for tracing the material when required.

4.11.2 Pipes and fittings are to be permanently marked by the manufacturer by moulding, hot stamping or by any other suitable method, such as printing, in accordance with 1.11. The markings are to include:
(a) Identification number, *see* 4.11.1.
(b) LR or Lloyd's Register, and the abbreviated name of LR's local office.
(c) Manufacturer's name or trademark.
(d) Pressure rating.
(e) Design standard.
(f) Material system with which the piping is made.
(g) Maximum service temperature.

4.12 Certification

4.12.1 The manufacturer is to provide the Surveyor with copies of the test certificates or shipping statements for all material which has been accepted.

4.12.2 Each test certificate is to contain the following particulars:
(a) Purchaser's name and order number.
(b) If known, the contract number for which the piping is intended.
(c) Address to which piping is despatched.
(d) Type and specification of material.
(e) Description and dimensions.
(f) Identification number, *see* 4.11.1.
(g) Test results.

■ *Section 5* Control of material quality for composite construction

5.1 Scope

5.1.1 This Section gives the general requirements for control of material quality when used in the construction of composite craft.

5.1.2 For composite craft built under the Rules, the survey of materials is to be conducted in accordance with the requirements of Sections 1 to 3 and this Section.

5.2 Design submission

5.2.1 The requirements for design submission are detailed in the appropriate Part of the Rules which includes full information on composite materials.

5.3 Construction

5.3.1 All constructions are to be carried out using materials approved or accepted by LR.

5.3.2 All materials are to be in accordance with the approved construction documentation.

5.3.3 All batches of materials are to be provided with unique identifications by their manufacturers. Components are to be similarly identified.

5.3.4 No batch of material is to be used later than its date of expiry.

5.3.5 The Builder is to ensure that all batches of materials are used systematically and sequentially.

5.3.6 The Builder is to maintain, on a continuous basis, records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the construction documentation.

5.3.7 Records are to be kept of the sequence and orientation of the reinforcements.

5.3.8 The Builder is to ensure that each section of the construction is traceable to the batch or batches of material used. The unique identifications required under 1.11.1 are to be included on all relevant quality control documentation.

5.3.9 Any curing system used is to be demonstrated as suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

5.3.10 The post-curing temperature is to be controlled and recorded by the attachment of suitably placed thermocouples.

5.4 Quality assurance

5.4.1 Where the Builder has a quality assurance system, this is to include the requirements of this Section.

5.5 Dimensional tolerances

5.5.1 Dimensions and tolerances are to conform to the approved construction documentation.

5.5.2 The thicknesses of the laminates are, in general, to be measured at not less than ten points, evenly distributed across the surface. In the case of large sections, at least ten evenly distributed measurements are to be taken in bands across the width at maximum spacing of two metres along the length.

5.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the Builder. Monitoring and random checking by the Surveyor does not absolve the Builder from this responsibility.

5.5.4 Where ultrasonic thickness gauges are used, these are to be calibrated against an identical laminate (of measured thickness) to that on which the thickness measurement is to be carried out. If suitable pieces are not available from the construction, then a small sample of identical lay-up is to be prepared.

5.6 Material composition

5.6.1 The materials, prefabricated sections or components used are to be in accordance with the approved construction documentation.

5.6.2 Where alternative materials are used, these are to be of approved or accepted types and the manufacturer is to demonstrate to the Surveyor's satisfaction, prior to their introduction, their suitability with respect to performance, otherwise full testing as appropriate will be required.

5.7 Material testing

5.7.1 Where so required, the material manufacturer is to provide the purchaser with certificates of conformity for each batch of material supplied, indicating the relevant values specified in 5.7.4 to 5.7.8. These values are to comply with those specified by the approved construction documentation.

5.7.2 Where the Builders do not conduct verification testing of the information indicated in 5.7.4 to 5.7.8, they are to ensure that copies of all certificates of conformity (which must indicate the actual tested values) are obtained for all batches of materials received, and maintain accurate records. The Surveyor may at any time select a sample of a material for testing by an independent, where applicable, source and should such tests result in the material failing to meet the specification, then that batch will be rejected.

5.7.3 The following tests are to be carried out, where applicable, on receipt of any material:

(a) The consignment is to be divided into its respective batches and each batch is to be labelled accordingly.
(b) Each batch is to be visually examined for conformity with the batch number, visual quality and date of expiry.
(c) Each batch is to be separately labelled and stored separately.
(d) Each unit, within the batch, is to be labelled with the batch number.
(e) Records are to be maintained of the above and these are to be cross-referenced with the certificate of conformity for the material and/or the Builder's own test results.

5.7.4 For thermosetting resins, reinforced or otherwise, the resin manufacturer is to have determined, on samples taken from each batch, at least the following:

(a) All resins:
  (i) Viscosity.
  (ii) Gel time.
  (iii) Filler content, where applicable.
(b) Polyester and vinylester resins:
  (i) Type (orthophthalic, isophthalic, etc.).
  (ii) Volatiles content.
  (iii) Acid value.
(c) Epoxide resins:
  (i) Free epoxide content.
(d) Phenolic resins:
  (i) Free phenol content.
  (ii) Free formaldehyde content.

5.7.5 For thermoplastics, the polymer manufacturer is to have made the following measurements on samples taken from each batch:

(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

5.7.6 Where the resin or polymer manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 5.7.4 or 5.7.5 as appropriate. The mixed batch is then to be given a unique batch number.

5.7.7 For reinforcements, the material manufacturer is to have recorded, where applicable, the following for each batch of material:

(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

5.7.8 For core materials, the following properties are to be recorded by the manufacturer for each batch:

(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.

(f) Surface treatment.
Together with the following mechanical properties:
In the case of rigid foams:
(g) Compressive strength (stress at maximum load) and modulus of elasticity.
(h) Core shear strength.
In the case of end-grain balsa:
(j) Tensile strength (stress at maximum load).
(k) Compressive strength (stress at maximum load) and modulus of elasticity.

5.7.9 During construction, tests are to be carried out on the constituents and final product in accordance with Table 14.5.1.

5.7.10 The standards of acceptance for testing are those listed in the material manufacturer's specification, approved construction documentation or agreed quality control procedures as applicable.

5.7.11 Laminate fibre content is to be determined at the request of the Surveyor, in particular where the thickness measured does not correlate with the specified fibre content, by weight. This will, in general, result in additional reinforcement being required.

5.7.12 If the batch of resin or polymer, or the curing agent, or their ratio is changed, at least two additional measurements of the gel time are to be carried out during each shift.

5.8 Visual examination

5.8.1 All constructional mouldings and any components are to be visually examined and are to be free from surface defects and blemishes.

5.9 Repair procedure

5.9.1 Repairs of minor cosmetic blemishes are permitted providing that these are brought to the attention of the Surveyor.

5.9.2 A repair procedure for these minor blemishes is to be included in the agreed quality control procedures.

5.9.3 Structural repairs are subject to individual consideration and full written details must be approved by the plan approval office prior to introduction.

5.10 Material identification

5.10.1 Records of the construction are to be kept in such a manner that traceability of all the component materials used is ensured. The Surveyor is to be given full facilities for tracing the material's origin when required.

5.10.2 Small representative samples of each batch of material are to be retained, these being suitably labelled to ensure traceability.

5.10.3 When so requested by the Surveyor, the Builder is to provide copies of all test data and/or manufacturers' certificates of conformity appertaining to any material used.

5.11 Minimum tested requirements for material approval

5.11.1 This Section provides the minimum property values required of a material for approval or acceptance by LR and are applicable to materials cured under ambient conditions.

Table 14.5.1 Testing during construction

Component/operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time	Two per shift
	Rate of consumption	Continuous
Reinforcement	Quality	Continuous
	Orientation	Continuous
	Rate of consumption	Continuous
Resin/reinforcement	Ratio	Continuous
Construction	Temperature during cure/post cure	Continuous
	Dimensions	Continuous against approved construction documentation
	Cure level (Barcol) against resin manufacturer's specification	At least one per square metre
	Laminate thickness	Continuous against material usage and approved construction documentation (*see also* 5.5.2 to 5.5.4)
	Laminate fibre content	At the Surveyor's request (*see* 5.7.11)

5.11.2 **Gel coat resins**. When the cast resin is tested according to the requirements of 2.3, Table 14.5.2 gives the minimum values for the respective properties.

Table 14.5.2 Gel coat resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,5%
Modulus of elasticity in tension	As measured
Flexural strength (stress at maximum load)	80 N/mm^2
Modulus of elasticity in flexure	As measured
Barcol hardness	As measured at full cure
Water absorption	70 mg (max)
Specific gravity of cast resin	As measured

5.11.3 **Laminating resins**. When tested according to the requirements of 2.3 and 2.4, Tables 14.5.3 and 14.5.4 give the minimum properties for the cast resin and chopped strand mat laminate respectively.

Table 14.5.3 Laminating resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,0%
Modulus of elasticity in tension	As measured
Flexural strength (stress at maximum load)	70 N/mm^2
Modulus of elasticity in flexure	As measured
Barcol hardness	As measured at full cure
Temperature of deflection under load	55°C
Specific gravity of cast resin	As measured

NOTE
These minimum values are for the recommended glass content by weight of 0,3.

5.11.4 When tested to the requirements of 2.4 for reinforcements, Table 14.5.5 gives the minimum properties for laminates.

Table 14.5.4 Laminating resins, minimum values for properties for CSM laminate at 0,3 glass fraction by weight

Properties	Minimum value
Tensile strength (stress at maximum load)	90 N/mm^2
Secant modulus at 0,25% and 0,5% strain respectively	6,9 kN/mm^2
Compressive strength (stress at maximum load)	125 N/mm^2
Compressive modulus	6,4 kN/mm^2
Flexural strength (stress at maximum load)	160 N/mm^2
Modulus of elasticity in flexure	5,7 kN/mm^2
Apparent interlaminar shear strength (*see* Note)	18 N/mm^2
Fibre content	As measured (0,3)
Water absorption	70 mg (max)

NOTE
Applicable only to the special test for environmental control resins.

5.11.5 Alternatively, materials may be approved by use of the actual tested values whereby the approval value shall equal the mean of the tested values minus twice the standard deviation of a minimum of five tested values.

5.12 Closed cell foams for core construction based on PVC or polyurethane

5.12.1 Table 14.5.6 gives minimum values for closed cell forms for core construction based on PVC or polyurethane.

5.12.2 Other types of foam will be subjected to individual consideration. A minimum core shear strength of 0,5 N/mm^2 is to be achieved.

5.13 End-grain balsa

5.13.1 Table 14.5.7 gives the minimum property requirement for end-grain balsa.

5.14 Other materials

5.14.1 All other materials will be subject to special consideration.

Table 14.5.5 Laminates, minimum property requirements

Material type	Property	Value
Chopped strand mat	Tensile strength (stress at maximum load) (N/mm^2)	$200G_c + 25$
	Modulus of elasticity in tension (kN/mm^2)	$15G_c + 2{,}0$
Bi-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$400G_c – 10$
	Modulus of elasticity in tension (kN/mm^2)	$30G_c – 0{,}5$
Uni-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$1800G_c^2 – 1400G_c + 510$
	Modulus of elasticity in tension (kN/mm^2)	$130G_c^2 – 114G_c + 39$
All	Flexural strength (stress at maximum load) (N/mm^2)	$502G_c^2 + 106{,}8$
	Modulus of elasticity in flexure (kN/mm^2)	$33{,}4G_c^2 + 2{,}2$
	Compressive strength (stress at maximum load) (N/mm^2)	$150G_c + 72$
	Compressive modulus (kN/mm^2)	$40G_c – 6$
	Interlaminar shear strength (N/mm^2)	$22 – 13{,}5G_c$ (min 15)
	Water absorption (mg)	70 (maximum)
	Glass content (% by weight)	As measured

NOTES
1. After water immersion, the values shall be a minimum of 75% of the above.
2. Where materials have reinforcement in more than two directions, the requirement will be subject to individual consideration dependent on the construction.
3. G_c = glass fraction by weight.

Table 14.5.6 Minimum characteristics and mechanical properties of rigid expanded foams at 20°C

<table>
<tr><th rowspan="2">Material</th><th rowspan="2">Apparent density kg/m³</th><th colspan="3">Strength (stress at maximum load) (N/mm²)</th><th colspan="2">Modulus of elasticity (N/mm²)</th></tr>
<tr><th>Tensile</th><th>Compressive</th><th>Shear</th><th>Compressive</th><th>Shear</th></tr>
<tr><td>Polyurethane</td><td>96</td><td rowspan="2">0,85</td><td rowspan="2">0,60</td><td rowspan="2">0,50</td><td rowspan="2">17,20</td><td rowspan="2">8,50</td></tr>
<tr><td>Polyvinylchloride</td><td>60</td></tr>
</table>

Table 14.5.7 Minimum characteristics and mechanical properties of end-grain balsa

<table>
<tr><th rowspan="4">Apparent density (kg/m³)</th><th colspan="5">Strength (stress at maximum load) (N/mm²)</th><th colspan="2" rowspan="2">Compressive modulus of elasticity (N/mm²)</th><th rowspan="4">Shear modulus of elasticity (N/mm²)</th></tr>
<tr><th colspan="2">Compressive</th><th colspan="2">Tensile</th><th rowspan="3">Shear</th></tr>
<tr><th colspan="4">Direction of stress</th><th colspan="2">Direction of stress</th></tr>
<tr><th>Parallel to grain</th><th>Perpendicular to grain</th><th>Parallel to grain</th><th>Perpendicular to grain</th><th>Parallel to grain</th><th>Perpendicular to grain</th></tr>
<tr><td>96</td><td>5,0</td><td>0,35</td><td>9,00</td><td>0,44</td><td>1,10</td><td>2300</td><td>35,2</td><td>105</td></tr>
<tr><td>144</td><td>10,6</td><td>0,57</td><td>14,6</td><td>0,70</td><td>1,64</td><td>3900</td><td>67,8</td><td>129</td></tr>
<tr><td>176</td><td>12,8</td><td>0,68</td><td>20,5</td><td>0,80</td><td>2,00</td><td>5300</td><td>89,6</td><td>145</td></tr>
</table>

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RULES AND REGULATIONS FOR THE CLASSIFICATION OF INLAND WATERWAYS SHIPS

SHIP STRUCTURES (GENERAL)

NOVEMBER 2008

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■ *Section 1* Rule application

1.1 General

1.1.1 The Rules apply in general to ships of normal form, proportions and speed. Relevant parameters to define what is regarded as normal are given by limitations specified at the beginning of individual ship type Chapters. Although the Rules are, in general, for steel ships of all welded construction, other materials for use in hull construction will be considered.

1.2 Exceptions

1.2.1 Ships of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special service, not covered by Parts 3 and 4, will receive individual consideration based on the general standards of the Rules.

1.3 Loading

1.3.1 The Rules are framed on the understanding that ships will be properly loaded, discharged and handled; they do not, unless it is stated or implied in the class notations, provide for special distributions or concentrations of cargo or handling (loading and discharging sequences). Additional strengthening may be required to be fitted in any ship which will be subjected to severe stresses due to particular features of the design, exceptional load or ballast conditions.

1.4 Advisory services

1.4.1 The Rules do not cover certain technical characteristics, such as stability, trim, vibration, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

■ *Section 2* Additional calculations

2.1 General

2.1.1 Where approval is required for ships defined under 1.2, involving novel features of hull design or designs outside the limitations of these Rules, Lloyd's Register (hereinafter referred to as LR) may require additional calculations or model testing to be carried out. In such cases, LR is willing to undertake calculations for designers and/or makerecommendations for model tests as required.

2.2 ShipRight direct calculation procedures

2.2.1 LR has direct calculation procedures and facilities available within the framework of the ShipRight procedures for the design, construction and lifetime care of ships.

■ *Section 3* Equivalents

3.1 Alternative arrangements

3.1.1 Alternative arrangements or fittings which are considered to be equivalent to those specified in the Rules will be accepted.

3.2 Alternative scantlings

3.2.1 In addition to cases where direct calculations are specifically required by the Rules for scantling assessment or confirmation purposes, LR will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule formulae. Where calculation procedures other than those available within ShipRight are employed, the assumptions made and the calculation procedure used are to be submitted for appraisal. The calculations are to be submitted for approval.

■ *Section 4* National and International Regulations

4.1 International Conventions

4.1.1 Attention is drawn to the necessity to comply with National and International Technical and Operational Regulations of countries, where the ship is registered or operating and which may also contain requirements which are outside classification as defined in these Rules, e.g.

- The 'Rhine Inspection Regulations' of the Central Rhine Commission (CCNR).

- The Regulations of the Central Rhine Commission (CCNR) concerning the transport of dangerous goods on the river Rhine (ADNR).
- The Regulations concerning the European Agreement on the International carriage of dangerous goods by River (ADN).

4.1.2 Ships for which a service extension notation is desired may require the issue of a Load Line Certificate.

4.1.3 The Committee, when authorized, will act on behalf of Governments in respect of National and International statutory safety and other requirements for passenger and cargo ships.

4.2 International Association of Classification Societies (IACS)

4.2.1 Where applicable, the Rules take into account unified requirements and interpretations established by IACS.

■ *Section 5* Information required

5.1 General

5.1.1 The categories and lists of information required are given in 5.2.

5.1.2 Plans are generally to be submitted in quadruplicate but one copy only is necessary for supporting documents and calculations.

5.1.3 Plans are to contain all necessary information to fully define the structure, including construction details, equipment and systems as appropriate.

5.1.4 Additional requirements for individual ship types are given in subsequent Chapters.

5.2 Plans

5.2.1 Plans suitably detailed covering the following items so far as applicable are to be submitted:
- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch cover construction.
- Deckhouses and superstructures.
- Sternframe.
- Rudders, stocks, and tillers.
- Cargo tanks, independent from the ship’s structure.
- Support structure for cargo tanks independent from the ship’s structure.
- Equipment.
- Ice strengthening.
- Welding.
- Support structure for masts, derrick posts or cranes.
- Loading manual.
- Liftable wheelhouse systems.

5.2.2 The following supporting documents are to be submitted:
- General arrangement.
- Capacity plan or equivalent information.
- Lines plan or equivalent.

5.2.3 The following supporting calculations are to be submitted:
- Calculation of equipment number, *see* Chapter 12.
- Calculation of hull girder still water bending moment and shear force as applicable, *see* Chapter 4.
- Calculation of midship section modulus, *see* Chapter 3.
- Calculations for structural items in the aft end, midship and fore end regions of the ship.

5.2.4 In cases where approval involves the use of computers, LR may require certain information to be given in a fixed format.

5.3 Plans to be supplied to the ship

5.3.1 To facilitate repairs and ordering materials for that purpose it is recommended that plans be carried in the ship as indicated in 5.2.1 so far as applicable. In case hull structural material other than Grade ‘A’ steel is incorporated in the ship, the disposition of this material and grades should be indicated on the plans with details of specification and mechanical and/or chemical properties, with recommendations for welding, working and treatment as may be necessary.

5.4 Fire protection, detection and extinction

5.4.1 For information and plans required, *see* Pt 6, Ch 1.

■ *Section 6* Definitions

6.1 Principal particulars

6.1.1 Rule length, *L*, is the distance, in metres, on the deepest load waterline from the forward side of the stem or rake plating to the after side of the aftermost rudder post, or to the centre of the aftermost rudder stock if there is no rudder post. *L* is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the deepest load waterline. In ships with unusual stern arrangements the Rule length, *L*, will be specially considered.

6.1.2 Amidships is to be taken as the middle of the Rule length, *L*, measuring from the forward side of the stem or rake plating.

6.1.3 Breadth, *B*, is the greatest moulded breadth, in metres.

6.1.4 Depth, *D*, is measured at the middle of the length, *L*, from top of keel to top of the deck beam at side on the uppermost continuous deck, or as defined in appropriate Chapters. When a rounded gunwale is arranged, the depth, *D*, is to be measured to the continuation of the moulded deck line, in metres.

6.1.5 Draught, *T*, is the maximum draught, measured from top of keel, in metres.

6.1.6 The block coefficient, C_b, is the moulded block coefficient at draught, *T*, corresponding to deepest load waterline, based on Rule length, *L*, and moulded breadth, *B*, as follows:

$$C_b = \frac{\text{moulded displacement (m}^3\text{) at draught } T}{LBT}$$

6.1.7 Length between perpendiculars, L_{pp}, is the distance, in metres, on the deepest load waterline from the fore side of the stem to the after side of the aftermost rudder post, or to the centre of the aftermost rudder stock if there is no rudder post. In ships with unusual stern arrangements the length, L_{pp}, will be specially considered. The forward perpendicular, F.P., is the perpendicular at the intersection of the deepest load waterline with the fore side of the stem or rake plating. The after perpendicular, A.P., is the perpendicular at the intersection of the deepest load waterline with the after side of the rudder post. For ships without a rudder post, A.P. is the perpendicular at the intersection of the waterline with the centreline of the aftermost rudder stock.

6.2 Passenger ship

6.2.1 A passenger ship is a ship which carries more than 12 passengers.

6.3 Reference system

6.3.1 For hull reference purpose, the ship is divided into 21 equally spaced stations where Station 0 is the after perpendicular, Station 20 is the forward perpendicular, and Station 10 is mid $-L_{pp}$.

6.4 Co-ordinate system

6.4.1 Unless otherwise stated, the co-ordinate system is as shown in Fig. 1.6.1, i.e. a right-hand co-ordinate system with the X axis positive forward, the Y axis positive to port and the Z axis positive upwards. Angular motions are considered positive in a clockwise direction about the X, Y or Z axes.

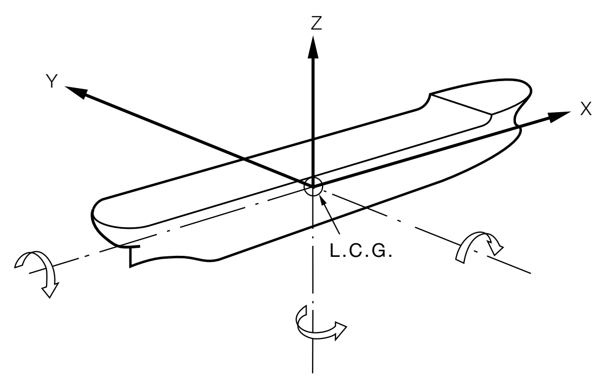


Fig. 1.6.1 Co-ordinate system

■ *Section 7* Inspection, workmanship and testing

7.1 Inspection

7.1.1 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection of all components during each stage of prefabrication and construction.

7.2 Workmanship

7.2.1 All workmanship is to be of good quality and in accordance with good shipbuilding practice. Any defect is to be rectified to the satisfaction of the Surveyor before the material is covered with paint, cement or other composition. The materials and welding are to be in accordance with the requirements of LR's *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). The assembly sequence and welding sequence are to be agreed prior to construction and are to be to the satisfaction of the Surveyor. Plates which have been subjected to excessive heating while being worked are to be satisfactorily heat treated before being erected in the hull.

7.2.2 **Wood sheathing on decks.** Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor.

7.2.3 **Rudder and sternframe.** The final boring out of the propeller boss and sternframe skeg or solepiece, and the fit-up and alignment of the rudder, pintles and axles is to be carried out after completing the major parts of the welding of the after part of the ship. Other methods will be specially considered. The contacts between conical surfaces of pintles, rudder stocks and rudder axles are to be checked before the final mounting.

7.3 Acceptance testing on completion

7.3.1 **Hose testing.** The items listed in Table 1.7.1 are to be carefully examined and hose tested to the satisfaction of the Surveyor.

7.3.2 **Pressure testing.** The items listed in Table 1.7.2 are to be subjected to the appropriate test head using water, however, a proposal for a combination of pressure testing and leak testing will be considered.

7.3.3 **Leak testing.** This test is carried out by applying a soapy water solution to the tank boundaries while the tank is subjected to an air pressure of 0,007 N/mm^2 (0,07 kgf/cm^2). It is recommended that the air pressure in the tank is raised to 0,010 N/mm^2 (0,10 kgf/cm^2), with a minimum number of personnel in the vicinity of the tank, and then lowered to the test pressure prior to inspection. Leak testing is normally to be carried out before a protective coating is applied. However, subject to careful inspection by the Surveyors, a complete protective coating may be applied prior to leak testing, except internally in way of welds made by processes other than automatic.

Table 1.7.1 Hose testing requirements

Item	Requirement
All ship types	
Watertight doors, in place	
Watertight bulkheads, flats and recesses	
Weathertight doors and other weathertight closing appliances	Pressure at least 0,2 N/mm^2 (2,0 kgf/cm^2) at maximum distance of 1,5 m from item under test, or equivalent
Weathertight steel hatch covers	
Oil tankers and chemical tankers	
Pumproom bulkheads not forming tank boundaries	
Remainder of pumproom space, *see* Note	

NOTE
To be carefully examined with the vessel afloat and if found satisfactory the hose-test may be dispensed with.

Table 1.7.2 Testing requirements (*see continuation*)

Item to be tested	Pressure testing requirements	Leak testing requirements – air pressure
All ship types, where appropriate		
Deep tanks, bunkers, peak tanks, side tanks, combined double bottom and side tanks, (including closing arrangements)	1 m head above the highest point of the tank, excluding hatchway, or to the top of the overflow, whichever is the greater, but is to be not less than 1ρ m above the top of the tanks where ρ is the relative density (specific gravity) of the intended cargo	0,007 N/mm^2 (0,07 kgf/cm^2)
Water ballast tanks	As for deep tanks	As for deep tanks
Cargo holds used for ballast	Depending on approved height of ballast in hold	As for deep tanks
Scupper and discharge pipes in way of tanks	As for deep tanks	As for deep tanks
Peak bulkheads not forming boundaries of tanks	Peaks to be filled with water to the level of the load waterline	—
Double plated rudders	1 m head, and rudder should normally be tested while laid on its side	0,01 N/mm^2 (0,10 kgf/cm^2), and arrangements made to ensure that no pressure in excess of 0,015 N/mm^2 (0,15 kgf/cm^2) can be applied
Double bottom tanks	Head of water representing the maximum pressure which could be experienced in service, or to the top of the overflow, whichever is the greater	0,007 N/mm^2 (0,07 kgf/cm^2)
Watertight doors (passenger ships)	Each door is to be tested to a head up to the bulkhead deck, either before or after fitting	Not applicable
Void spaces (not accessible)	—	0,007 N/mm^2 (0,07 kgf/cm^2)
Tankers not carrying dangerous liquids in bulk		
Cargo tanks, cofferdams and cargo tanks not forming part of the ship's structure	1 m head of water above the highest point of the tank, excluding hatchway, or to top of hatchways for cofferdams, but is to be not less than 1ρ m above the top of the tank where ρ is the relative density (specific gravity) of the intended cargo	0,007 N/mm^2 (0,07 kgf/cm^2)

Table 1.7.2 Testing requirements (*conclusion*)

Item to be tested	Tanker type	Pressure testing requirements	Leak testing requirements – Air pressure
Tankers carrying dangerous liquids in bulk, *see* Pt 4, Ch 6			
Cargo tanks and independent cargo tanks	G	Depending on properties of liquid	Not applicable
Cargo tank hatchways and covers	C and N Closed with design pressures from 10 up to and including 15 kPa	Tank to be subjected to a head of water of 0,13 x (design pressure in kPa) above top tank, excluding hatchways, *see* Note 1	
	C and N Closed with design pressures greater than 15 up to and including 50 kPa	Tank to be subjected to a head of water of 0,13 x (design pressure in kPa) above top tank, excluding hatchways	0,007 N/mm^2 (0,07 kgf/cm^2)
	N Open with flame screens and N Open	1 m head of water above top of tank or 0,50 m above top of hatchway, whichever is greater	
Cofferdams with hatchways	G, C and N Closed, N Open with flame screens and N Open	1 m head of water above top of the cofferdam	0,007 N/mm^2 (0,07 kgf/cm^2)

NOTES
1. If the relative density (specific gravity) of the cargoes on which the scantlings of the tanks are based, is in excess of 1 these test heads are to be multiplied by a factor equal to the relative density, but this factor should not be taken greater than 1,2.
2. The cargo tanks and cofferdams are to be tested using water.
3. In no case is the test pressure to be more than is indicated on the approved plans.

7.3.4 When a preservative coating is to be applied to the internal structure of a tank, the water testing may take place after the application of the preservative, provided that the structure is carefully examined to ensure that all welding and structural stiffening is completed prior to the application of the coating, excluding prefabrication primers. The cause of any discolouration or disturbance of the coating is to be ascertained, and any deficiencies repaired. The attachment of fittings to oiltight surfaces should be completed before tanks are tested.

7.3.5 Pressure testing may be carried out afloat where testing using water is undesirable in dry-dock or on the building berth. The testing afloat is to be carried out by separately filling each tank and cofferdam to the test head. For tankers, the testing afloat is to be carried out by separately filling each tank and cofferdam to the test head given in Table 1.7.2. With about half the number of tanks full, the bottom and lower side shell in the empty tanks is to be examined and the remainder of the bottom and lower side shell examined when the water is transferred to the remaining tanks. The sequence of tank testing is not to lead to unacceptable stresses being imposed upon the hull girder.

7.3.6 If, on cargo tanks of tankers, structural pressure testing has been carried out prior to the fitting of measuring devices, pipe connections and other equipment with passages through the deck or through the cargo hatch additional leak tests are to be carried out in order to verify the tightness in way.

7.4 Trial trip and operational tests

7.4.1 The items listed in Table 1.7.3 are to be tested on completion of the installation or at sea trials.

Table 1.7.3 Trial trip and operational tests

Item	Requirement
Sliding watertight doors	To be operated under working conditions.
Windlass	An anchoring test (bow and stern anchors) is to be carried out in the presence of the Surveyors. The test should demonstrate that the windlass with brakes, etc., functions satisfactorily and that the power to raise anchor can be developed.
Steering gear, main and auxiliary	To be tested under working conditions, to the satisfaction of the Surveyors. Power operated steering gear is to be capable of moving the completely immersed rudder, whilst the ship is running ahead at maximum service speed, from 30° on either side to 30° on the other side within 15 seconds.
Bilge suctions in holds, and hand pumps in peak spaces	To be tested under working conditions to the satisfaction of the Surveyors.

■ *Section 1* Materials of construction

1.1 General

1.1.1 These Rules relate, in general, to the construction of steel ships, although consideration will be given to the use of other materials, when permitted by the Regulations of National and/or International Authorities for the type of ship.

1.1.2 The materials used in the construction of the ship are to be manufactured and tested in accordance with the requirements of Lloyd's Register's (hereinafter referred to as LR) *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Materials for which provision is not made in LR's Rules for Materials may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.

1.1.3 Where steel castings or forgings are used for stern-frames, rudder frames, rudder stocks, propeller shaft brackets and other major structural items, they are to comply with LR's Rules for Materials, Chapters 4 or 5, as appropriate.

1.1.4 Where aluminium alloy is used for superstructures, deckhouses, hatch covers or other structural components, equivalent scantlings are to be derived.

1.2 Grades of steel

1.2.1 The ships covered by these Rules are generally to be constructed of Grade 'A' steel. In highly stressed areas, however, grades of steel with higher levels of notch toughness (Grades 'B', 'D' or 'E') may be required, dependent on the thickness of the material and the stress pattern associated with its location.

■ *Section 2* Corrosion protection

2.1 General

2.1.1 All steelwork, except inside tanks intended for the carriage of oil or bitumen and inside void spaces which are permanently sealed, is to be suitably protected against corrosion. This may be by coating or by any other approved method. For the protection required in tanks carrying chemicals or other special cargoes, *see* Pt 4, Chapters 4, 5, 6, and 7.

2.1.2 Where bimetallic connections are made, measures are to be incorporated to preclude galvanic corrosion.

2.2 Surface preparation, prefabrication primers, and paints or coatings

2.2.1 Steelwork is to be suitably cleaned and cleared of millscale before the application of surface paints and coatings. It is recommended that blast cleaning or other equally effective means be employed for this purpose.

2.2.2 Where a primer is used to coat steel after surface preparation and prior to fabrication, and which is not type approved by LR for this purpose, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied.

2.2.3 To determine the influence of the primer coating on the characteristics of welds, tests are to be made to the Surveyors' satisfaction.

2.2.4 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used. Unless previously agreed, at least two coats are to be applied.

2.2.5 The paint or coating is to be compatible with any previously applied primer, *see* 2.2.2.

2.2.6 Paints, varnishes and similar preparations having a nitrocellulose or other highly flammable base are not to be used in accommodation or machinery spaces.

2.2.7 In ships intended for the carriage of oil cargoes having a flash point below 55°C, paint containing aluminium should not, in general, be used in positions where cargo vapours may accumulate, unless it has been shown by appropriate tests that the paint to be used does not increase the incendive sparking hazard.

■ *Section 3*
Deck covering

3.1 General

3.1.1 Where plated decks are sheathed with wood or an approved composition, reductions in plate thickness may be allowed.

3.1.2 The steel deck is to be coated with a suitable material in order to prevent corrosive action. Where sheathing or composition is used, it is to be effectively secured to the deck.

3.1.3 Deck coverings in the following positions are to be of a type which will not readily ignite when used on decks:
(a) forming the crown of machinery or cargo spaces within accommodation spaces of cargo ships;
(b) within accommodation spaces, control stations, stairways and corridors of passenger ships.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter illustrates the general principles to be adopted in applying the Rule structural requirements given in Parts 3 and 4. In particular, consideration has been given to the layout of the Rules as regards the different regions of the ship, principles for taper of hull scantlings, definition of span point, derivation of section moduli and basic design loading for deck structures.

1.1.2 Where additional requirements relating to particular ship types apply, these are, in general, dealt with under the relevant ship type Chapter in Part 4.

■ *Section 2* Rule structural concepts

2.1 Definition of requirements

2.1.1 In Fig. 3.2.1, the breakdown of the ship into regions is shown. Within each region, the applicable Parts and Chapters of the Rules are indicated.

2.2 Definition of midship region

2.2.1 The midship region structure is considered to include the structure within the greater of:

(a) the midship 0,5*L*, length,

(b) the cargo compartment length which on tankers includes the cofferdams and/or pump-rooms under deck.

2.3 Definition of fore end region

2.3.1 The fore end region structure is considered to include all structure forward of the midship region.

2.4 Definition of aft end region

2.4.1 The aft end region structure is considered to include all structure aft of the midship region.

2.5 Principles for taper

2.5.1 The thickness of the shell envelope and deck outside the line of openings between the 0,5*L* midship and 0,075*L* from the A.P. and 0,075*L* from the F.P., may be based on a direct taper from the midship thickness to the end thickness, as shown in Fig. 3.2.2, except where required otherwise in Part 4.

2.6 Principles for rounding off

2.6.1 The thickness of hull structural components calculated by using the formulae for these components should be rounded off for so far as they deviate from full or half millimetres according to Table 3.2.1.

Table 3.2.1 Principles for rounding off

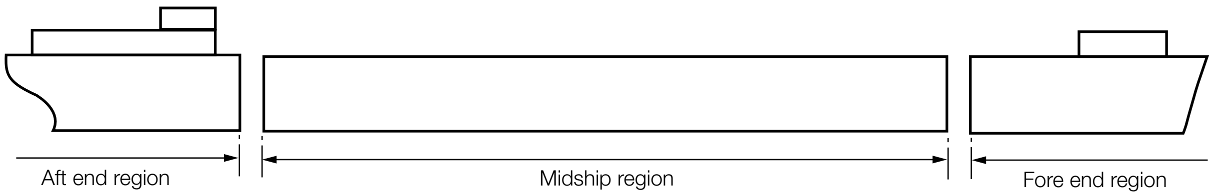
Thickness in excess of whole number by		Rounded to
Over	Not exceeding	
—	0,2 mm	0
0,2 mm	0,7 mm	0,5 mm
0,7 mm	1,0 mm	1,0 mm

2.7 Frame spacing

2.7.1 The frame spacing of transverse or longitudinal frames is generally to be within the range given by the following formula:

$$S = (340 + 23\sqrt{L - 10}) \pm 70 \text{ mm}$$

Proposals for frame spacings different from this range will be specially considered.



0,5*L* or cargo compartment length, including cofferdams and/or pumprooms below deck, whichever is the greater

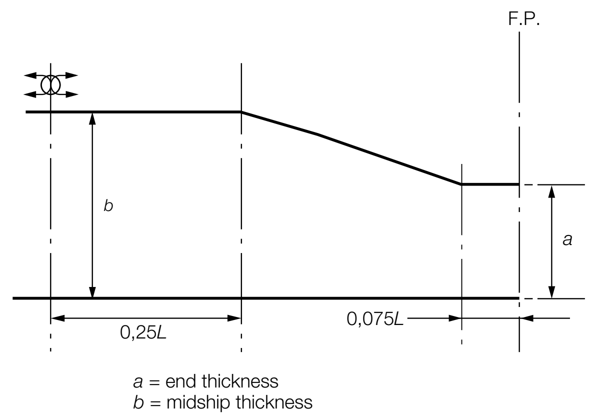
Sections covered	Part	Ch
Aft end structure	3	5
Rudders	3	12

Sections covered	Part	Ch
Hull scantlings	4	—
Longl. strength	3	4

Sections covered	Part	Ch
Fore end structure	3	5

Sections covered	Part	Chapter
Testing	3	1
Materials	3	2
Machinery spaces	3	6
Bulkheads	3	7
Superstructures	3	8
Special features	3	9
Welding and structural details	3	10
Closing arrangements, etc.	3	11
Ship control systems	3	12
Equipment	3	12

Fig. 3.2.1 Breakdown of the ship into regions



a = end thickness
b = midship thickness

Fig. 3.2.2 Principles for taper

■ *Section 3*
Structural idealization

3.1 General

3.1.1 For derivation of scantlings of stiffeners, beams, girders, etc., the formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, associated with an appropriate concentrated or distributed load.

3.1.2 The properties of stiffener, beam or girder are defined by a section modulus and a moment of inertia. Apart from local requirements for web thickness, the minimum thickness in relation to the plating to which it is connected is to comply with Table 3.3.1. Primary members are also to comply with the requirements of Ch 10,4.

Table 3.3.1 Minimum web plating thickness in relation to the connected plating

Plating thickness	Web thickness
3,5 – 5 mm	4 mm
6 – 7 mm	5 mm
8 – 9 mm	6 mm
above 9 mm	7 mm

3.1.3 For flat bar stiffeners, the ratio of depth to thickness should not exceed 16.

3.2 Geometric properties of section

3.2.1 The symbols used in this sub-Section are defined as follows:

l = the overall length, in metres, of the support member, *see* Fig. 3.3.1

b = the actual width, in metres, of the load-bearing plating, i.e. one-half of the sum of spacings between parallel adjacent members or equivalent supports, *see* Fig. 3.3.2

t_p = the thickness, in mm, of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used

$f = 0{,}3 \left(\frac{l}{b}\right)^{2/3}$ but is not to exceed 1,0

Values of this factor are given in Table 3.3.2.

Table 3.3.2 Values of *f* as a function of *l/b*

$\frac{l}{b}$	f	$\frac{l}{b}$	f
0,5	0,19	3,5	0,69
1,0	0,30	4,0	0,76
1,5	0,39	4,5	0,82
2,0	0,48	5,0	0,88
2,5	0,55	5,5	0,94
3,0	0,62	6 and above	1,00
NOTE Intermediate values to be obtained by linear interpolation.			

3.2.2 The effective geometric properties of rolled of built sections may be calculated directly from the dimensions of the section and associated effective area of attached plating. Alternatively, the geometric properties may be taken from Section 5. Where the web of the section is not normal to the attached plating, the angle is not normal to the attached plating, and exceeds 20, the properties of the section are to be determined about an axis parallel to the attached plating, alternatively, the required section modulus is to be multiplied by a factor:

$$= 1 + 0{,}01 \left(\frac{90 - \alpha}{7}\right)^2$$

where

α is the angle between stiffener and plating.

3.2.3 The geometric properties of rolled or built stiffener sections are to be calculated in association with an effective area of attached load bearing plating of thickness t_p in mm and of width 500 mm; for swedges, the width of plating is to be taken as the actual width of flat plating between the swedges. The thickness, t_p, is the actual thickness of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.4 The effective section modulus of a corrugation over a spacing, s, is to be calculated from the dimensions and for symmetrical corrugations, may be taken as:

$$Z = \frac{d_w}{6000} (3bt_p + ct_w) \quad \text{cm}^3$$

where d_w, b, t_p, c and t_w are measured, in mm, and are as shown in Fig. 3.3.3. The value of b is to be taken not greater than $50t_p$ in this calculation, and θ is to be not less than 40°. The moment of inertia is to be calculated from:

$$I = \frac{Z}{10} \left(\frac{d_w}{2} + t_p\right) \quad \text{cm}^4$$

3.2.5 For symmetrical corrugations, the following additional requirements are also to be complied with:

(a) the ratio b/t_p should not exceed 70

(b) the ratio c/t_p should not exceed 85

(c) d_w is to be not less than $39l_e$ mm (for deep tank bulkheads only),

(d) the plating thickness at the middle of span l_e of corrugated bulkheads is to extend not less than $0{,}2l_e$ above mid span, (for definition of l_e, *see* 3.3).

3.2.6 The effective section modulus of a built section may be taken as:

$$Z = \frac{ad_w}{10} + \frac{t_w\, d_w^2}{6000} \left(1 + \frac{200(A - a)}{200A + t_w\, d_w}\right) \quad \text{cm}^3$$

where

a = the area of the face plate of the member, in cm^2

A = the area, in cm^3, of the attached plating, *see* 3.2.7. If the calculated value of A is less than the face area a, then A is to be taken as equal to a

d_w = the depth of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken, in mm

t_w = the thickness of the web of the section, in mm

Rolled or built sections fitted on top of supported stiffening members, *see* Fig. 3.3.4, are to have a modulus not less than two thirds of the modulus required for the primary member in the same position. This section should be attached at both ends of the plating for at least one stiffener spacing and should also be properly attached to the supported stiffeners.

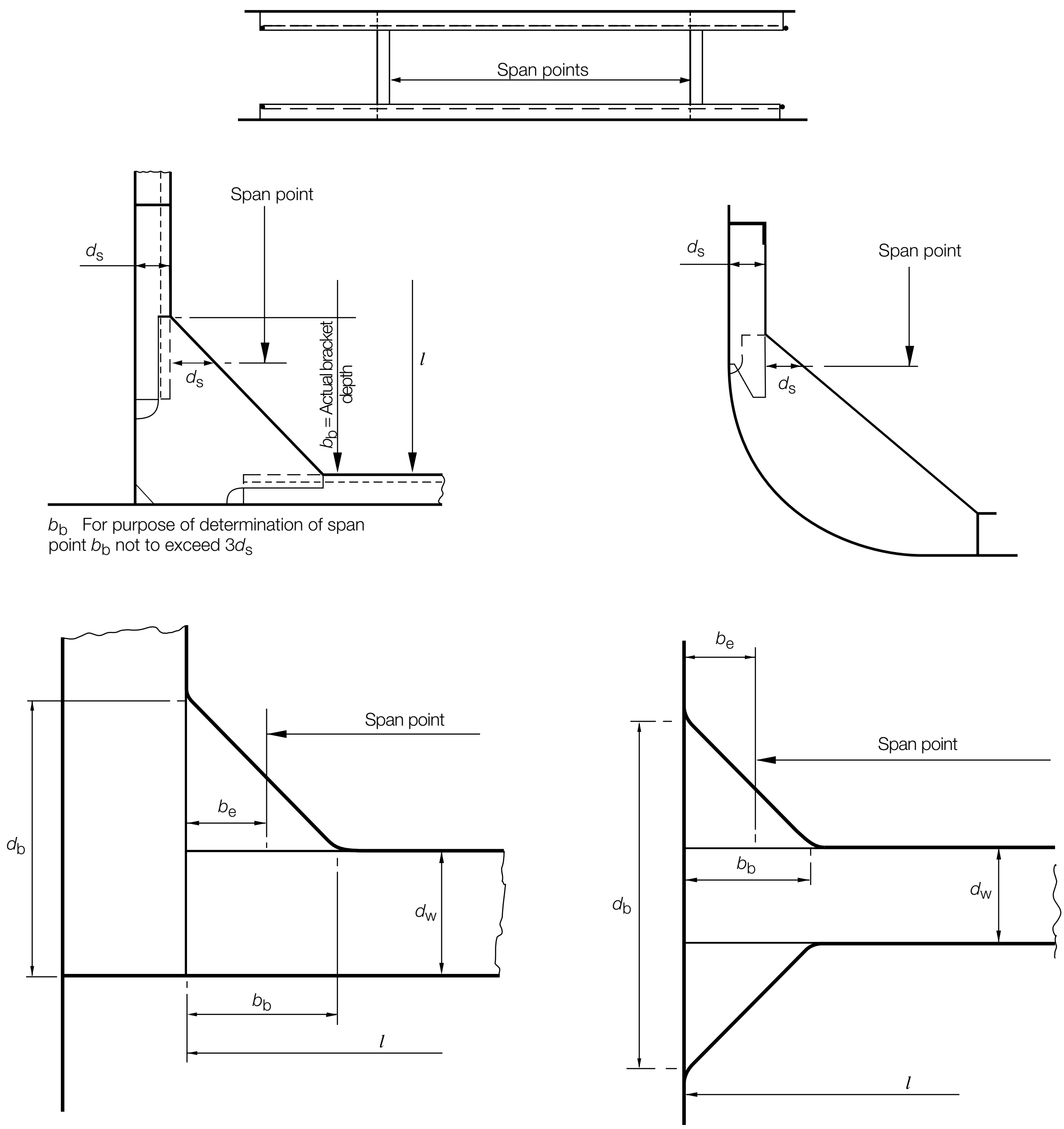


Fig. 3.3.1 Determination of span points

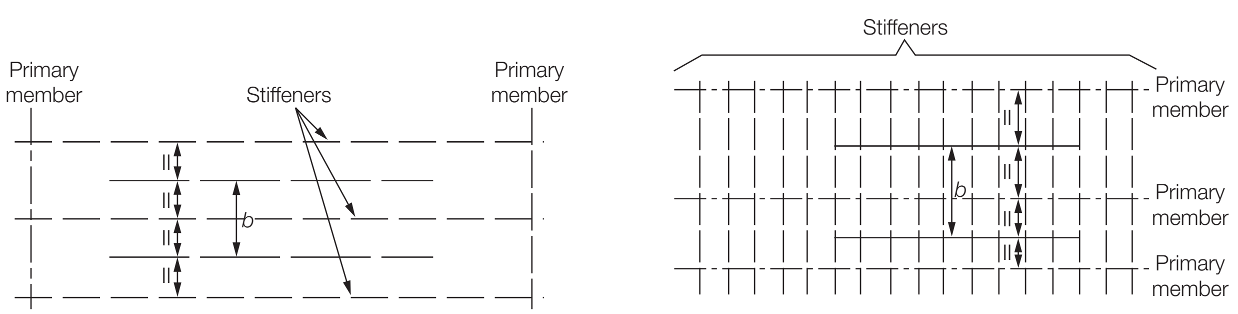


Fig. 3.3.2 Determination of load bearing plating

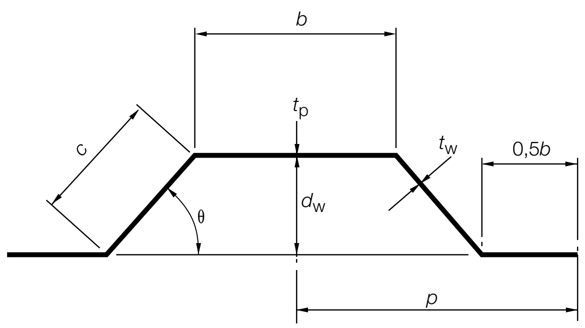


Fig. 3.3.3
Dimensions and symbols for corrugated bulkheads

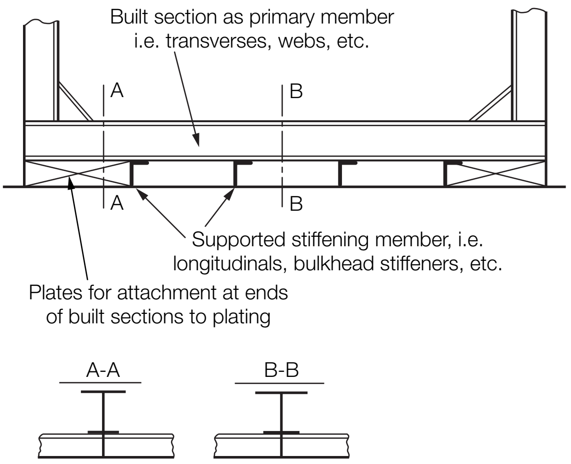


Fig. 3.3.4
Rolled or built sections fitted on top of supported stiffening members

3.2.7 The geometric properties of primary support members, i.e. girders, transverses, webs, stringers, etc., are to be calculated in association with an effective area of attached load bearing plating, *A*, determined as follows:

(a) For a member attached to plane plating:
$A = 10fbt_p$ cm^2 (for *f*, *see* Table 3.3.2)

(b) For a member attached to corrugated plating and parallel to the corrugations:
$A = 10bt_p$ cm^2
See Fig. 3.3.3

(c) For a member attached to corrugated plating and at right angles to the corrugations:

A is to be taken as equivalent to the area of the face plate of the member.

3.3 Determination of span point

3.3.1 The effective span, l_e, of a stiffening member is generally less than the overall length, *l*, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built stiffener sections, swedges and corrugations:
The span point is to be taken at the point where the depth of the end bracket, measured from the face of the stiffener is equal to the depth of the stiffener. Where there is no Rule end bracket, the span point is to be taken at the end of the stiffener.

(b) For primary support members, i.e. girders, transverses, webs, stringers, etc.:
The span point is to be taken at a point distant, b_e, from the end of the member,

where:

$$b_e = b_b\left(1 - \frac{d_w}{d_b}\right)$$

See also Fig. 3.3.1.

3.3.2 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

3.4 Calculation of hull section modulus

3.4.1 All continuous longitudinal structural material is to be included in the calculation of the inertia of the hull midship section, and the lever *z* is, except where otherwise specified for particular ship types, to be measured vertically from the neutral axis to the top of keel and to the moulded strength deck line at the side. The strength deck is to be taken as follows:

(a) Where there is a complete upper deck and no effective superstructure, the strength deck is the upper deck.

(b) Where there is an effective superstructure or a stepped deck, the position of the strength deck will be specially considered.

3.4.2 An effective superstructure is a superstructure extending over the full breadth of the ship and which exceeds 0,20*L* in length or 10 m whichever is the greater and is situated within the 0,5*L* region.

3.4.3 Lightening holes in girders need not be deducted, provided that their depth does not exceed 20 per cent of the web depth.

3.4.4 Isolated weld scallops, drain and air holes in longitudinals need not be deducted, provided that their depth does not exceed 65 mm. In no case is the opening to be greater than 25 per cent of the web depth. Such openings are considered isolated if they are spaced not less than 1 m apart.

3.4.5 In general, isolated deck openings need not be deducted, but compensation may be required. *See* individual ship type Chapters.

3.4.6 Where continuous hatch coamings are arranged, 80 per cent of the effective continuous material of the coaming with longitudinal stiffening may be included in the calculation of hull section modulus, and the lever z is to be measured to the effective height of the hatch coaming, i.e. moulded deck line at side amidships plus height of hatch coaming including camber.

3.4.7 Where continuous hatch coamings are supported by longitudinal bulkheads or equivalent structure, the sectional area of the effective height of the coaming may be fully included in the calculation of the section modulus.

3.4.8 Where a trunk deck is fitted, 100 per cent of the area of the trunk may be included in the calculation of hull section modulus, and the lever z is measured to the edge of trunk deck, *see* individual ship type Chapters.

■ *Section 4* Design loading

4.1 General

4.1.1 This Section contains the design heads/pressures to be used in the derivation of scantlings for decks, tank tops and transverse bulkheads. Where scantlings in excess of Rule requirements are fitted, the procedure to be adopted to determine the permissible loading pressure which may be carried by such scantlings is given in Table 3.4.1.

Table 3.4.1 Design heads and permissible cargo loading (SI units) (*see continuation*)

	Rule Loading				
Structural item and position	Component	Stowage rate, in m^3/tonne	Design loading p, in kN/m^2	Design head h_i, in metres	Permissible cargo loading, in kN/m^2
Upper deck outside of accommodation spaces				h_1	
Loading for minimum scantlings	All structure	1,39	4,59	0,65	4,59
Cargo decks, tanktop or hold ceiling				h_2	
General cargo (standard loads)	All structure	1,39	$7{,}07H_c$	H_c	$7{,}07H_c$
Machinery space, workshop and stores	All structure	1,39	18,37	2,6	18,37
Ship stores	All structure	1,39	9,22	1,3	9,22
Accommodation decks	All structure	1,39	3,18	$h_3 = 0{,}45$	3,18
Watertight bulkheads	Plating and stiffeners	1	h_4	h_4 from Fig. 3.4.2	
Deep tank bulkheads	Plating and stiffeners	1	h_4	h_4 from Fig. 3.4.2	
Hatch covers (standard loading) *see* Note	All structure	1,39	1,47	$h_H = 0{,}21$	1,47
	Applied loading				
Upper deck outside of accommodation spaces				h_1	
Specified cargo loading	All structure	C	p_a	$\dfrac{Cp_a}{9{,}82}$	p_a
Cargo decks, tanktop or hold ceiling				h_2	
Special cargo (specified loads)	All structure	C	p_a	$\dfrac{Cp_a}{9{,}82}$	p_a
Deep tank bulkheads	Plating and stiffeners	C but ≤ 1	$\dfrac{h_4}{C}$	h_4 from Fig. 3.4.2	
Hatch covers (specified loading)	All structure	C	p_a	$h_H = \dfrac{Cp_a}{9{,}82}$	p_a

NOTE
For ships operating in Zone 3 only, hatchcovers may be designed for a minimum design loading of 0,075 tonne-f/m^2 plus the selfweight of the covers.

Table 3.4.1 Design heads and permissible cargo loading (metric units) (*conclusion*)

Structural item and position	Component	Stowage rate, in m^3/tonne	Design loading p, in tonne-f/m^2	Design head h_i, in metres	Permissible cargo loading, in tonne-f/m^2
	Rule loading				
Upper deck outside of accommodation spaces				h_1	
Loading for minimum scantlings	All structure	1,39	0,468	0,65	0,468
Cargo decks, tanktop or hold ceiling				h_2	
General cargo (standard loads)		1,39	$\frac{H_c}{1,39}$	H_c	$\frac{H_c}{1,39}$
Machinery space, workshop and stores	All structure	1,39	1,87	2,6	1,87
Ship stores		1,39	0,94	1,3	0,94
Accommodation decks	All structure	1,39	0,324	h_3 = 0,45	0,324
Watertight bulkheads Deep tank bulkheads	Plating and stiffeners	1	h_4	h_4 from Fig. 3.4.2	
Hatch covers (standard loading) *see* Note	All structure	1,39	0,15	h_H = 0,21	0,15
	Applied loading				
Upper deck outside of accommodation spaces				h_1	
Specified cargo loading	All structure	C	p_a	Cp_a	p_a
Cargo decks, tanktop or hold ceiling				h_2	
Special cargo (specified loads)	All structure	C	p_a	Cp_a	p_a
Deep tank bulkheads	Plating and stiffeners	C but ≤ 1	$\frac{h_4}{C}$	h_4 from Fig. 3.4.2	
Hatch covers (specified loading)	All structure	C	p_a	$h_H = Cp_a$	p_a

NOTE
For ships operating in Zone 3 only, hatchcovers may be designed for a minimum design loading of 0,075 tonne-f/m^2 plus the selfweight of the covers.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

p = design loading which is either the Rule loading as defined in Table 3.4.1 or the applied loading p_a, whichever is the greater, in kN/m^2 (tonne-f/m^2)

p_a = applied loading, i.e. the actual loading specified by the builder or the Owner, in kN/m^2 (tonne-f/m^2)

h_i = design head, which is to be used in the Rule formulae, in metres
= p x C where p has been defined in tonne-f/m^2, or
= p x C/9.81 where p has been defined in kN/m^2

C = stowage rate, in m^3/tonne
$= \dfrac{\text{volume of hold, in m}^3}{\text{weight of cargo, in tonnes}}$ for inner bottom or hold ceiling
$= \dfrac{h_i}{p}$ elsewhere

l_e = span of stiffener, in metres

H_c = height from inner bottom, hold ceiling or cargo deck, to deck at side or underside of hatch covers or height of deck cargo, in metres, as defined in Fig. 3.4.1(a) or (b).

4.3 Stowage rate and design loads

4.3.1 Unless it is specifically requested otherwise, the following Rule standard stowage rates are to be used:

(a) 1,39 m^3/tonne for weather or general cargo loading on deck and inner bottom or hold ceiling.

(b) 1,0 m^3/tonne for liquid cargo of density of 1 tonne/m^3 or less on watertight and tank divisions. For liquid of density greater than 1 tonne/m^3, the corresponding stowage rates are to be adopted.

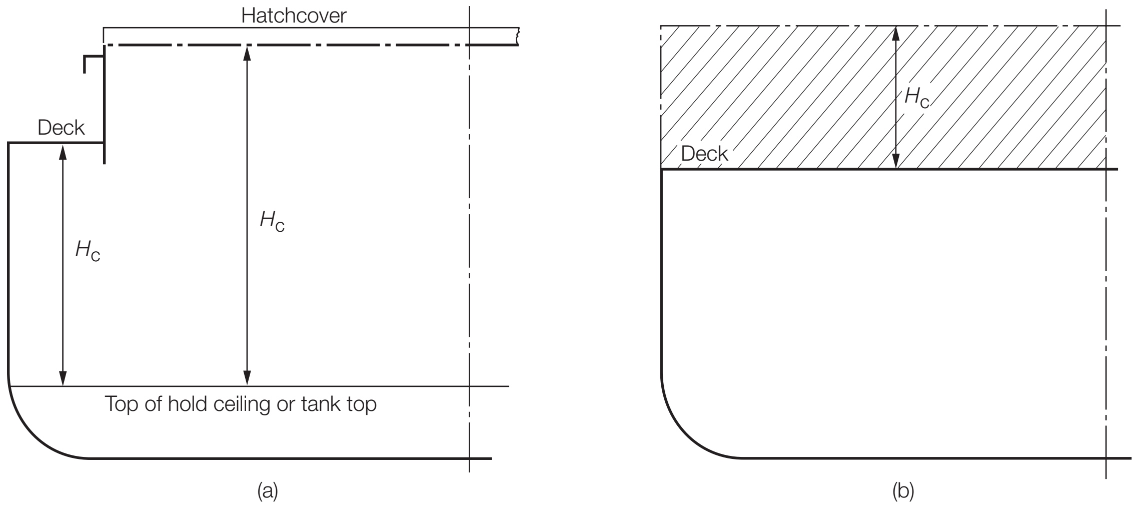


Fig. 3.4.1 Design heads for inner bottoms and 'tweendecks

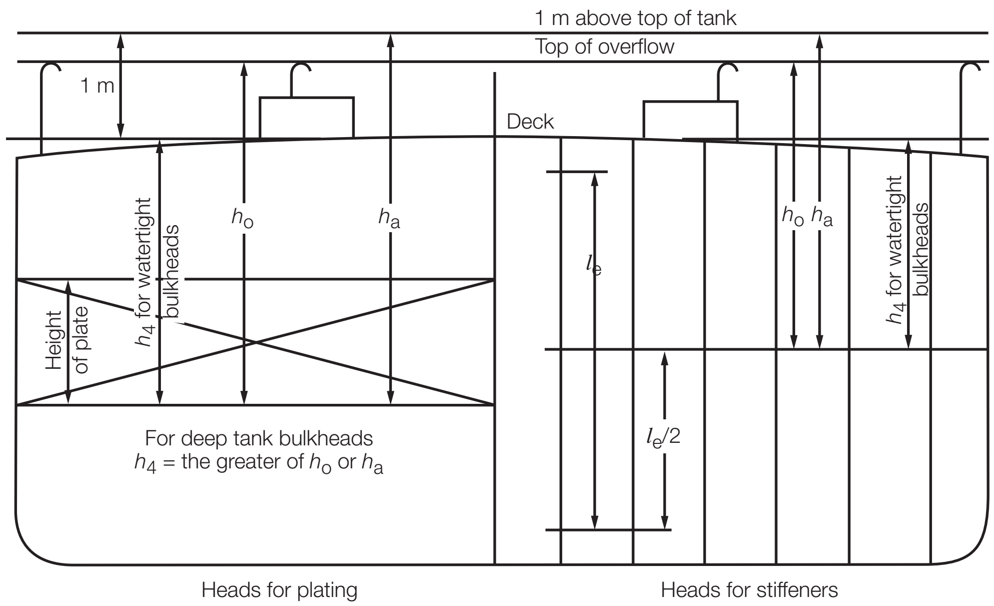


Fig. 3.4.2 Heads for watertight and deep tank bulkheads

4.3.2 Proposals to use a stowage rate greater than 1,39 m^3/tonne for permanent structure will require special consideration, and will normally be accepted only in the case of special purpose designs.

4.3.3 The design head and permissible cargo loading are shown in Table 3.4.1.

■ *Section 5* Geometric properties of rolled sections

5.1 General

5.1.1 For convenience, geometric properties of rolled sections may be derived from Tables 3.5.1, 3.5.2 and 3.5.3. Alternatively the effective geometric properties of rolled sections may be calculated directly from dimensions of the section and associated area of attached plating.

Table 3.5.1 **Inverted angle bars**

	Plating thickness 4 – 8 mm			Plating thickness 9 – 12 mm		
	A, in cm^2 of section only	I, in cm^4	Z, in cm^3	A, in cm^2	I, in cm^4	Z, in cm^3
45 x 45 x 4	3,49	45	10			
45 x 45 x 6	5,09	59	14			
50 x 50 x 5	4,80	67	15			
60 x 40 x 5	4,79	92	16			
50 x 50 x 6	5,69	75	17			
50 x 50 x 8	7,41	90	21	7,41	118	24
60 x 40 x 7	6,55	115	22	6,55	142	24
60 x 60 x 6	6,91	128	25			
65 x 50 x 7	7,6	149	27	7,6	189	30
80 x 40 x 6	6,89	203	29			
60 x 65 x 6	7,53	161	30			
60 x 60 x 8	9,03	152	31	9,03	197	35
65 x 50 x 9	9,58	173	33	9,58	223	36
75 x 50 x 7	8,3	207	34	8,3	259	37
80 x 40 x 8	9,01	245	36	9,01	298	39
80 x 60 x 6	8,11	250	36			
65 x 65 x 8	9,85	191	37	9,85	247	41
70 x 70 x 7	9,4	218	39	9,4	279	43
75 x 50 x 9	10,5	240	40	10,5	308	44
100 x 50 x 6	8,73	364	45			
70 x 70 x 9	11,9	251	48	11,9	330	52
80 x 60 x 8	10,6	309	48	10,6	380	51
100 x 50 x 8	11,5	435	56	11,5	550	61
80 x 80 x 8	12,3	368	58	12,3	445	63
100 x 65 x 7	11,2	462	60	11,2	584	65
100 x 75 x 7	11,9	499	66	11,9	635	71
80 x 80 x 10	15,1	417	69	15,1	513	74
100 x 65 x 9	14,2	534	73	14,2	693	79
100 x 75 x 9	15,1	662	84	15,1	754	88
90 x 90 x 10	17,1	620	90	17,1	741	96
100 x 75 x 11	18,2	696	95	18,2	855	102
130 x 65 x 8	15,1	906	96	15,1	1160	103
90 x 90 x 12	20,3	683	103	20,3	828	110
130 x 75 x 8	15,9	1045	107	15,9	1250	113
100 x 100 x 10	19,2	777	111	19,2	964	118
130 x 65 x 10	18,6	1110	116	18,6	1343	124
100 x 100 x 12	22,7	850	126	22,7	1070	135
130 x 75 x 10	19,6	1266	129	19,6	1446	135
150 x 75 x 9	19,5	1545	142	19,5	1865	151
130 x 75 x 12	23,3	1405	148	23,3	1620	156
120 x 120 x 10	23,2	1371	164	23,2	1656	173
150 x 75 x 11	23,6	1848	169	23,6	2194	179
150 x 90 x 10	23,2	1924	178	23,2	2210	186
120 x 120 x 12	27,5	1505	187	27,5	1841	199
150 x 100 x 10	24,2	1895	188	24,2	2340	200
150 x 90 x 12	27,5	2126	204	27,5	2464	214
150 x 100 x 12	28,7	2085	215	28,7	2607	230
130 x 130 x 12	30	1732	216	30	2207	232
180 x 90 x 10	26,2	2902	228	26,2	3336	239
130 x 130 x 14	34,7	1860	241	34,7	2398	260
180 x 90 x 12	31,2	3218	263	31,2	3732	276
200 x 100 x 10	29,2	3866	282	29,2	4460	295
150 x 150 x 12	34,8	2540	290	34,8	3259	310
200 x 100 x 12	34,8	4278	325	34,8	4977	341
150 x 150 x 15	43	3056	348	43	3659	367

Table 3.5.2 Flat bars

	Plating thickness 4 – 8 mm			Plating thickness 9 – 12 mm		
	A, in cm^2	*I*, in cm^4	*Z*, in cm^3	*A*, in cm^2	*I*, in cm^4	*Z*, in cm^3
50 x 5	2,5	23	5			
50 x 7	3,5	31	6	3,5	39	7
60 x 5	3	38	6			
65 x 5	3,25	47	7			
50 x 9	4,5	39	8	4,5	49	9
60 x 7	4,2	51	9	4,2	62	10
65 x 7	4,55	64	10	4,55	76	11
60 x 9	5,4	64	11	5,4	77	13
75 x 6	4,5	83	12			
65 x 9	5,85	79	13	5,85	95	15
75 x 8	6	106	16	6	125	17
75 x 10	7,5	135	19	7,5	152	21
90 x 7	6,3	164	19	6,3	182	21
90 x 9	8,1	203	25	8,1	227	26
100 x 8	8	245	27	8	272	28
90 x 11	9,9	250	30	9,9	269	32
110 x 8	8,8	319	32	8,8	353	34
100 x 10	10	308	34	10	330	35
110 x 10	12,1	383	39	12,1	428	42
100 x 12	12	358	40	12	385	41
110 x 12	13,2	443	46	13,2	498	49
130 x 9	11,7	555	49	11,7	617	51
130 x 11	14,3	680	60	14,3	729	62
130 x 13	16,9	806	71	16,9	835	72
150 x 10	15	930	72	15	996	74
150 x 12	18	1115	86	18	1154	88
150 x 14	21	1256	99	21	1302	101

Table 3.5.3 Holland profiles

	Plating thickness 4 – 8 mm			Plating thickness 9 – 12 mm		
	A, in cm^2 of section only	*I*, in cm^4	*Z*, in cm^3	*A*, in cm^2	*I*, in cm^4	*Z*, in cm^3
80 x 5	5,4	158	21			
80 x 7	7	186	25	7	213	27
100 x 6	7,74	320	35			
100 x 8	9,74	367	42	9,74	420	44
120 x 6	9,31	534	51			
120 x 8	11,71	608	59	11,71	695	63
140 x 7	12,4	892	76	12,4	1016	80
140 x 9	15,2	999	87	15,2	1151	92
160 x 7	14,8	1357	104	14,8	1556	110
160 x 9	17,8	1491	117	17,8	1728	124
180 x 8	18,9	2064	148	18,9	2396	156
180 x 10	22,5	2246	165	22,5	2633	175
200 x 9	23,5	2968	200	23,5	3483	212
200 x 11	27,6	3196	220	27,6	3785	235
220 x 10	29	4169	268	29	4950	285
220 x 12	33,4	4387	287	33,4	5244	307
240 x 10	32,4	5371	325	32,4	6412	346
240 x 12	37,3	5724	354	37,3	6877	379
260 x 11	38,7	7097	415	38,7	8549	443
260 x 13	43,3	7421	439	43,3	8959	471

■ *Section 1* Application

1.1 General

1.1.1 The requirements of this Chapter apply to both self-propelled ships with machinery aft and to non-propelled ships (barges and pontoons).

1.1.2 For the determination of the longitudinal strength, design bending moments are to be calculated for all ships with a length, *L*, exceeding 40 m. The methods for calculation of design bending moments are given in Section 5. The determination of longitudinal strength of ships with a length, *L*, of 40 m and less is generally not required.

1.1.3 The longitudinal strength of self-propelled ships where the machinery space is not situated aft and the length, *L*, exceeds 40 m will be specially considered; the design bending moments are to be determined by direct calculation.

■ *Section 2* General

2.1 Loading conditions for determination of design bending moments

2.1.1 The following conditions are to be covered by the calculations of design bending moments:

(a) Light condition (ship completely equipped, fresh water tanks, fuel tanks and lubricating oil tanks full, crew and stores on board and tanks partly filled or full with water ballast if intended to be carried in this condition).
(b) Fully loaded condition, ship as in light condition and loaded with cargo, as evenly distributed as is practicable in the cargo compartment space, to the maximum allowable draught on even keel.
(c) Any other loading condition of the ship giving higher values of bending moments or shear forces, caused by loading and discharging sequences and/or unusual or non-uniform cargo distribution, *see also* Pt 1, Ch 2,2.1.7, 2.1.8 and ship type Chapters.

2.1.2 For ships designed, modified and/or arranged for navigation in Zones 2 or 1 or for service extension, the additional wave bending moment and wave shear force for the particular zone or service extension area are to be added to the still water bending moment and shear force calculated for the conditions (a) and (b) of 2.1.1 to obtain the actual maximum bending moment and shear force for calculation of the required hull section modulus.

2.1.3 For ships sailing in Zone 3, *see* Pt 1, Ch 2,2.1.3, it is acceptable to calculate the bending moments and shear forces for the still water condition only, neglecting the wave bending moments and wave shear forces.

2.1.4 The maximum still water bending moment corresponding to the ship's longitudinal strength category, *see* 2.3, may not be exceeded when the ship is partly loaded due to navigational or operational requirements.

2.1.5 The longitudinal strength will be specially considered for ships designed, modified and/or arranged for any unusual loading condition, uneven cargo distribution, etc.

2.2 Definition of loading sequences 'T', 'O' and 'D'

2.2.1 Loading/discharging sequence 'T', for normal loading sequence.

Self-propelled ships with machinery aft:
Loading of the ship in two runs of practically equal mass, by distributing the cargo evenly over the full length of the cargo compartment space. The loading is to commence from the after end and to progress to the forward end and then be completed by loading from forward to aft.
Discharging in two runs of practically equal mass, taking the cargo evenly from the full length of the cargo compartment space, progressing from the after end to forward and completing the discharging from forward to aft.

Non-propelled ships:
Loading and discharging in two runs of practically equal mass, by distributing the cargo evenly over the full length of the cargo compartment and discharging by taking the cargo evenly from the cargo compartment space. The loading may be carried out from forward to aft and be completed from aft to forward or in the opposite direction. Discharging may be carried out in the same manner as loading.

2.2.2 Loading/discharging sequence 'O' for accelerated loading sequence.

Self-propelled ships with machinery aft:
Loading in one run. Loading to commence from the after end of the cargo compartment space and to progress to the forward end with the total mass of cargo evenly distributed.
Discharging in one run. Discharging to commence from the forward end of the cargo compartment space and to progress to the aft end.

Non-propelled ships:
Loading in one run, which may be commenced either from the forward end or the after end and evenly distributing the total mass of cargo to complete the loading at the other end of the cargo compartment space.
Discharging in one run, which may be commenced either from the forward or the after end of the cargo compartment space.

2.2.3 Loading/discharging sequence 'D' for defined loading sequence.

2.3 Longitudinal strength categories

2.3.1 For the purpose of longitudinal strength (L.S.), the Rules distinguish between three ship categories, defined as follows:

Category 'T'
Ships for which the required section modulus is based on the maximum bending moments and shear forces occurring when the ships are being loaded and/or discharged according to the loading sequence 'T', *see* 2.2 and/or ship type Chapter.

Category 'O'
Ships for which the required section modulus is based on the maximum bending moments and shear forces occurring when the ships are being loaded and/or discharged according to the loading sequence 'O', *see* 2.2 and/or ship type Chapter.

Category 'D'
At special request, acceptance of the required section modulus on the basis of lower design bending moment and shear forces than those associated with the loading sequence 'T', will be considered. However, these bending moments are generally not to be less than as given for MH_{1i} and MS_{1o} in Table 4.5.2. Where the notation L.S.'D' is assigned, a manual containing approved loading conditions as well as approved loading and discharge sequences is to be carried on board.

2.4 Specified non-uniform loading conditions

2.4.1 At special request the longitudinal strength, i.e. the required section modulus, may be based on bending moments and shear forces occurring in unusual and/or non-uniform loading conditions, in addition to those occurring when the ship is being loaded and/or discharged according to the loading sequence 'T' or 'O' as applicable. These bending moments and shear forces are to be verified by direct calculations and a manual containing the approved loading conditions as well as the approved loading and discharge sequences for the non-uniform conditions is to be carried on board.

2.5 Erections contributing to hull strength

2.5.1 Where a long superstructure or deckhouse of a length greater than 0,2*L* is fitted, extending within the 0,5*L* amidships, the longitudinal strength of the hull including the long superstructure or deckhouse will be considered in each case, *see also* Pt 3, Ch 3,4.

2.6 Approved calculation systems

2.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular ship may be submitted.

■ *Section 3* Information required

3.1 List of requirements

3.1.1 The information as required by Ch 1,5 is to be submitted.

3.1.2 For ships of which the design bending moments are to be verified by direct calculation, *see* Section 5, the following additional information is to be submitted:

(a) Bonjean data, in tabular form or curves, for the ship at sufficient equally spaced stations forward and aft depending on the shape of the ship.
(b) The actual light weight of the ship and its distribution over the length *L* of the ship. Where an assumed distribution is submitted, data in support of the assumption may be required.
(c) Details of cargo weights and their centres of gravity for each condition indicated in 2.1.
(d) Details of loading and discharging sequences, if applicable.

■ *Section 4* Hull section modulus

4.1 General

4.1.1 The hull section modulus required over 0,5*L* amidships is to be determined from the design bending moments, sagging or hogging, *see* Section 5, in association with a permissible stress as indicated in Section 6.

4.1.2 The calculation of the actual hull section modulus is to comply with the requirements of Ch 3,3.4.

Section 5
Design bending moments

5.1 General

5.1.1 The design bending moments, sagging and hogging, are the maximum moments occurring when the ship is in any condition indicated in 2.1.

5.1.2 The design bending moments may be determined, using the formulae given in this Section, but will be verified by direct calculations for ships with unusual or non-uniform load distribution and for ships of a length, L, exceeding 65 m or as specified in Pt 4, Ch 5,4.1, Ch 6,2.1 and Ch 7,3.1.1.

5.1.3 The design bending moments of ships with a length, L, between 40 mm and 65 mm may be determined using the formulae given in this Section. Alternatively, the design bending moments may be determined using an approved direct calculation system.

5.2 Calculation of design bending moment using formulae

5.2.1 The design bending moments (still water condition) to be distinguished and the formulae to be used are given in Table 4.5.1 and Table 4.5.2.

Table 4.5.1 Design bending moments

	Self-propelled ships		Non-propelled ships	
	Hogging	Sagging	Hogging	Sagging
Ships of longitudinal strength, Category 'T'	MH_T	The greater of: MS_T, or MS_{lo}	MH_T	MS_T
Ships of longitudinal strength, Category 'O'	MH_O	MS_O	MH_O	MS_O

Symbols (applicable to Tables 4.5.1 and 4.5.2)

L, B, D, T and C_b are as defined in Ch 1,6

r = ratio of $\dfrac{L_c}{L}$

L_c for dry cargo ships = length of hold(s)

L_c for tankers = cargo compartment length excluding cofferdams at fore and aft end

MH_{li} = Hogging moment in light condition, *see* 2.1.1(a)

MH_O = Hogging moment of ships with loading sequence 'O', *see* 2.1.1(c)

MH_T = Hogging moment of ships with loading sequence 'T', *see* 2.1.1(c)

MS_{lo} = Sagging moment in fully loaded condition, *see* 2.1.1(b)

MS_O = Sagging moment of ships with loading sequence 'O', *see* 2.1.1(c)

MS_T = Sagging moment of ships with loading sequence 'T', *see* 2.1.1(c)

Table 4.5.2 Design bending moments in relation to longitudinal strength category

Moment, in tonne-f m	Self-propelled ships	Non-propelled ships
MH_{li}	$(0{,}9 - 0{,}0013L) \times MH_O$	
MH_O	$(1{,}98r - 0{,}45)\,(K_1\,B\,T + K_2)\,L^2$	$(0{,}0166 - 0{,}0088C_b)\,L^2\,B\,T \times (3{,}97r - 2{,}414)$
MH_T	$0{,}92 \times MH_O$	$(2{,}23 - 1{,}67C_b)\,MH_O$
MS_{lo}	$(0{,}118C_b - 0{,}0958)\,L^2\,B\,T + 0{,}092\,(0{,}73 - r)\,L^2\,B\,T$	$(0{,}95C_b - 0{,}0806)\,L^2\,B\,T + 0{,}1\,(0{,}86 - r)\,L^2\,B\,T$
MS_O	$(K_3\,B\,T - K_4)\,L^2 + (0{,}24C_b - 0{,}148)\,(0{,}73 - r) \times L^2\,B\,T$	$(0{,}091C_b - 0{,}068)\,L^2\,B\,T \times (4{,}18 - 3{,}7r)$
MS_T	$(2C_b - 1{,}08) \times MS_O$	$(2C_b - 1{,}08)\,MS_O$
For symbols, *see* Tables 4.5.1 and 4.5.3		

Table 4.5.3 Self-propelled ships with machinery aft

Block coefficient C_b	Hogging moment		Sagging moment	
	K_1	K_2	K_3	K_4
0,75	0,01039	0,07512	0,00668	0,08080
0,76	0,01050	0,07329	0,00741	0,08149
0,77	0,01058	0,07147	0,00817	0,08217
0,78	0,01064	0,06964	0,00895	0,08284
0,79	0,01067	0,06782	0,00975	0,08350
0,80	0,01068	0,06599	0,01056	0,08415
0,81	0,01066	0,06416	0,01139	0,08479
0,82	0,01061	0,06234	0,01225	0,08542
0,83	0,01054	0,06052	0,01312	0,08604
0,84	0,01044	0,05869	0,01401	0,08665
0,85	0,01031	0,05687	0,01492	0,08724
0,86	0,01015	0,05504	0,01584	0,08783
0,87	0,00997	0,05322	0,01679	0,08841
0,88	0,00976	0,05140	0,01775	0,08898
0,89	0,00953	0,04958	0,01874	0,08953
0,90	0,00927	0,04775	0,01974	0,09000
0,91	0,00898	0,04593	0,02076	0,09062
0,92	0,00867	0,04411	0,02180	0,09114
0,93	0,00833	0,04229	0,02286	0,09166
0,94	0,00796	0,04047	0,02394	0,09217
0,95	0,00757	0,03865	0,02504	0,09266

Section 6
Maximum permissible stresses

6.1 General (Zone 3)

6.1.1 The permissible stresses to be used for the calculation of the hull section modulus are:

(a) Longitudinal bending:

σ_s = 137 N/mm^2 (14 kgf/mm^2)

(b) In ships with continuous hatch coamings: Longitudinal bending at top of coaming

σ_s = 137 N/mm^2 (14 kgf/mm^2)

6.1.2 The permissible combined stress, σ_c, being the sum of stresses due to longitudinal bending and local loading ($\sigma_c = \sigma_s + \sigma_b$) is:

σ_c = 177 N/mm^2 (18 kgf/mm^2)

6.1.3 The compressive stress in deck and bottom plating due to longitudinal bending is not to exceed the value given by the following expressions:

Transverse framing:

$$\sigma = 0{,}157 \left(\frac{t}{S}\right)^2 \times \left(\frac{S}{s} + \frac{s}{S}\right)^2 \text{ N/mm}^2$$

$$\left(\sigma = 0{,}016 \left(\frac{t}{S}\right)^2 \times \left(\frac{S}{s} + \frac{s}{S}\right)^2 \text{ kgf/mm}^2\right)$$

Longitudinal framing:

$$\sigma = 0{,}49 \left(\frac{t}{S}\right)^2 \text{ N/mm}^2$$

$$\left(\sigma = 0{,}05 \left(\frac{t}{S}\right)^2 \text{ kgf/mm}^2\right)$$

where

t = thickness of plating, in mm
s = frame spacing, in metres
S = spacing longitudinal stiffening members or girders, in metres

6.1.4 For additional maximum stress requirements, *see* respective ship type Chapter.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all types of ships covered by Part 4 except where otherwise specifically stated.

1.1.2 The requirements given are those specific to the fore end and aft end regions, *see* Ch 3,2.3 and Ch 3,2.4.

1.1.3 Requirements for the cargo space structure are as detailed in the relevant Chapters of Part 4 for the particular ship type.

1.2 Structural configuration

1.2.1 The Rules provide for both longitudinal and transverse framing systems or a combination of both.

1.3 Structural continuity

1.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

1.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover.

1.3.3 Where steps or breaks are situated in the upper-deck, suitable scarfing arrangements are to be provided, and the sheerstrake is to be increased in thickness in this region. This also applies to the ends of a trunk deck.

1.3.4 In ships having continuous side tanks or double skin construction in way of the cargo spaces, the longitudinal bulkheads are to be continued as far forward and aft as is practicable and are to be suitably tapered at their ends. Where, due to the ship's form, these bulkheads are stepped, suitable scarfing is to be arranged.

1.4 Symbols and definitions

1.4.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D and *T* are as defined in Ch 1,6.1

s = spacing of secondary stiffeners, i.e. frames, beams, or stiffeners, in metres

S = spacing, or mean spacing, of primary members, i.e. girders, transverses, webs, etc., in metres

l = overall length of stiffening member, in metres, *see* Ch 3,3.2

l_e = effective length of stiffening member, in metres, *see* Ch 3,3.3

I = inertia of stiffening member, in cm^4, *see* Ch 3,3.2

Z = section modulus of stiffening member, in cm^3, *see* Ch 3,3.2

t = thickness of plating, in mm

P_p = maximum designed shaft power of the propulsion machinery installed in the ship, in kW

H_p = maximum designed shaft power, in shp, of propulsion machinery installed in the ship.

1.4.2 For the purpose of this Chapter, the forward perpendicular (F.P.) is defined as the forward limit of the Rule length, *L*, and the aft perpendicular (A.P.) is defined as the after limit of the Rule length, *L*.

■ *Section 2* Hull envelope plating

2.1 General

2.1.1 This Section covers the requirements for hull envelope plating, which includes keel, stem, bottom shell plating, bilge plating, side shell plating, sheerstrake and deck plating for the fore end and aft end of the ship. Requirements are also given for tapering between the end thickness and the midship 0,5*L* thickness.

2.2 Keel

2.2.1 The scantlings of bar keels at the ends are to comply with Table 5.2.1.

2.2.2 The thickness of the keel plate forward of the collision bulkhead is to be the stem plate thickness; aft of the collision bulkhead the keel plate thickness is to be as required for the midship region. The width of the keel plate is to be 0,1*B* at the collision bulkhead and may be tapered towards the stem.

2.2.3 The thickness of the keel plate aft is to be as required for the midship region. The width of the keel plate is to be 0,1*B* at the aft peak bulkhead and may be tapered towards the aft end.

Table 5.2.1 Shell plating forward and aft

Location	Scantlings
(1) Keel bars	t = 0,37L + 10 mm Height = 0,7L + 75 mm
(2) Stem (a) Bar stem (b) Plate stem	The greater of: A = 0,6L cm^2 A = 10 cm^2 t = 0,08L + 5 mm
(3) Bottom shell, bilge and side shell plating forward and aft of the respective shoulders (a) Forward of 0,075L from the F.P. and aft of 0,075L from the A.P. (end thickness) (b) Between 0,075L and 0,25L from the F.P. and between 0,075L and 0,25L from the A.P.	The greater of: t = $(5,6 + 0,054\sqrt{L})\,s$ mm t = 10s mm The taper thickness as determined from the midship thickness and the end thickness using a taper line as per Ch 3,2.4
(4) Bilge chine bars (a) Round bars (b) Solid square bars (c) Angle bars in square bilges	The greater of: Diameter = 3t_a mm Diameter = 30 mm The greater of: Width = 3t_a mm Width = 30 mm Flange thickness = 2t_a mm
Symbols	
L, s and t are as defined in 1.4.1 A = cross-sectional area of bar stem, in cm^2 t_a = thickness of the bottom plating amidships, in mm	

2.3 Stem

2.3.1 Bar stems may be rolled steel bars or steel forgings complying with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials (*hereinafter referred to as Rules for Materials). The scantlings of bar stems are to comply with Table 5.2.1.

2.3.2 The thickness of plate stems is to be determined from Table 5.2.1. Plate stems are to be supported by horizontal diaphragms, spaced about 1 m apart and extended to the nearest frame. Where the stem plate radius is large, a centreline stiffener or web will be required. The thickness of plate stems from 1 m above the deepest load waterline may be equal to the local shell thickness.

2.3.3 For sternframe details, *see* Section 8.

2.4 Shell plating

2.4.1 The thickness of bottom shell, bilge and side shell plating in the forward and aft region is to comply with Table 5.2.1, but may require to be increased as per 4.2.3.

2.4.2 The amidships thickness of the bilge plating is to be extended forward and aft to include the shoulders of the bilge. The shoulder is regarded to extend to where the upper edge of the bilge strake forward and aft reaches the point 0,5B – 0,5 m.

2.4.3 Where a bilge chine bar is used in a bilge arrangement, the scantlings of chine bars are to comply with Table 5.2.1, and adjacent bottom and side shell plating need not be increased in thickness.

2.4.4 The thickness of side shell and sheerstrake plating in the forward and aft region may require to be increased locally in accordance with Chapter 4, on account of high shear forces, or the presence of steps or breaks in decks, *see* 1.3.3.

2.4.5 The thickness of shell plating is to be increased locally in way of the sternframe, propeller brackets and rudder trunks. The increased plate thickness is to be not less than 50 per cent greater than the basic shell end thickness. The shell plating in way of hawse pipes is to be increased in thickness by 3 mm.

2.4.6 Where a swim end is arranged, the bottom shell plating thickness amidships is to be maintained up to the end of the rake plating.

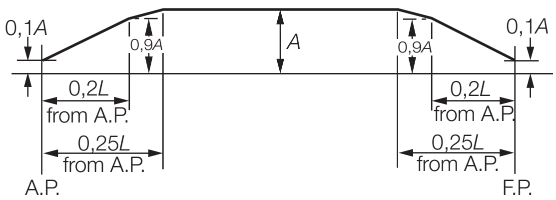
2.5 Shell openings

2.5.1 In general, compensation will not be required for holes in the shell plating forward and aft, provided the holes are of well rounded shape, but reinforcements in way of large openings may be required.

2.6 Deck plating

2.6.1 The thickness of deck plating is to comply with the requirements of Table 5.2.2.

2.6.2 For ships with wide hatch openings, in addition to the requirements for minimum deck thickness forward given in 2.6.1, the total cross-sectional area of strength deck plating and longitudinal stiffening outside the line of main hatch openings is to be not less than that obtained from a taper line constructed as shown in Fig. 5.2.1.



A = total cross sectional area of deck plus longitudinal stiffening outside line of main hatch openings amidships

Fig. 5.2.1 Strength deck area taper

2.6.3 The deck plating thickness and supporting structure are to be suitably reinforced in way of the anchor windlass, steering gear and other deck machinery, and in way of bollards, cranes, masts or derrick posts.

2.6.4 For steps and breaks, *see* 1.3.3.

2.7 Deck openings

2.7.1 Compensation and edge reinforcement for openings in the upperdeck forward of 0,25*L* from the F.P. and aft of 0,25*L* from the A.P. may be required.

Table 5.2.2 Deck plating forward and aft

Location	Thickness, in mm
(1) Forward of 0,075*L* from the F.P. and aft of 0,075*L* from the A.P. on the strength deck	The greatest of: $t = (5,6 + 0,039L)\sqrt{s}$ $t = 10s$ $t = 3,5$
(2) Between 0,075*L* and 0,25*L* from the F.P. and between 0,075*L* and 0,25*L* from the A.P. on the strength deck	The greatest of: $t = (5,6 + 0,039L)\sqrt{s}$ $t = 10s$ $t = 3,5$ t = the taper thickness *see* Note
(3) Platform decks	The greater of: $t = 8s$ $t = 3,5$
(4) In way of crown or bottom of a tank	The greater of: t = as required in Chapter 7 t as in (1), (2) or (3) as applicable,but not less than t = 5 mm for oil tanks, or t = 5,5 mm for water ballast tanks
(5) Plating forming the upper flange of underdeck girders	The greater of: $t = \sqrt{A_f}$ with a minimum breadth b = 0,75 m t as in (1), (2), (3) or (4), as applicable
Symbols	
L, *s* and *t* are as defined in 1.4.1 A_f = girder face area, in cm^2 b = breadth of increased plating, in metres	
NOTE For taper area requirements, *see also* 2.6.2.	

■ *Section 3*
Bottom structure

3.1 General

3.1.1 Requirements are given in this Section for both transversely and longitudinally framed bottoms.

3.1.2 Additional requirements for bottom structure in way of the machinery space are given in Chapter 6.

3.1.3 Provision is to be made for free passage of water, oil and air from all parts of single or double bottoms, and account being taken of the pumping rates required.

3.2 Girders

3.2.1 A centreline girder is to be arranged in ships having a breadth of more than 6 m, and is to be carried as far forward and aft as practicable and is to comply with the requirements of Table 5.3.1 or Table 5.3.2.

3.3 Single bottom – Transverse framing

3.3.1 Plate floors are to be fitted at every frame and the scantlings are to comply with the requirements of Table 5.3.1. The depth of floors at the centreline is to be as required in Table 5.3.1, but in ships having considerable rise of floor towards the ends, the depth of floors may require to be increased, or the top edge sloped upwards towards the outboard end, *see* Fig. 5.3.1. If required floors may be cut at the centreline, with the girder web plate continuous, but the strength of the floors is to be maintained in way of the centre girder connection. Notwithstanding the requirements for the fitting of a centreline girder as per 3.2.1, suitable arrangements to prevent tripping of the floors, e.g. riders or tripping brackets, are to be provided, where the unsupported length of the top edge of the floors exceeds 20b m;
where

b is the width in metres of the face plate of the floor.

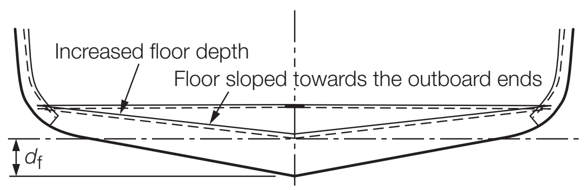


Fig. 5.3.1 Basic floor arrangements

3.3.2 The centre girder is to have the same depth as the floors.

Table 5.3.1 Single bottom construction forward and aft

Item	Parameter	Requirements
Transverse framing system		
(1) Floors	Web depth at centreline Modulus Web thickness	d_f = 40l_f mm Z = 6 x D_1 x s x l_f^2 cm^3 t = 0,01d_f + 2 mm
(2) Centreline girder	Web and face plate thickness Face plate width	t = 0,01d_f + 2 mm w = 140s mm
Longitudinal framing system		
(3) Centreline girder	Modulus Web thickness	Z = 8,5 x D_1 x S x l_e^2 cm^3 t = 0,01d_f + 2 mm
(4) Bottom transverses	Modulus Web thickness	Z = 7 x D_1 x S x l_e^2 cm^3 t = as centreline girder
Symbols		
B, D, T, S, s, l_e, Z and t are as defined in 1.4.1 D_1 = D but need not be taken greater than T + 0,4 m d_f = depth of floor or bottom transverse at centreline, in mm l_f = span of the floor, and is normally the breadth of the ship measured on the top of the floor under consideration, in metres. If longitudinal bulkheads or equivalent floor supports are provided an equivalent breadth may be used, but this should be not less than 0,4B w = width of face plate of a member, in mm		
NOTE The thickness of plates forming the single bottom structure is to be not less than 5 mm.		

Table 5.3.2 Double bottom construction forward and aft

Item	Parameter	Requirements
Transverse and longitudinal framing system		
(1) Centre girder	Least depth	The greater of: $d_f = \dfrac{12 \times D_1 \times l_b^2}{t_1}$ mm; d_f = 300 mm
	Thickness	$t = 0{,}01d_f + 1$ mm
(2) Inner bottom plating	Thickness for dry spaces	$t = 10s$
	Thickness for tanks	The greater of: $t = 12s$ mm; t = as required by Ch 7,2
(3) Struts	Cross-sectional area	Area = $2 \times l_e \times D_1 \times s$ cm^2
(4) Watertight floors	Thickness	The thickness of plate floors + 0,5 mm
Transverse framing system		
(5) Plate floors and brackets of bracket floors	Thickness	$t = 0{,}008d_f + 1$ mm
(6) Bottom frames in bracket floors	Modulus	$Z = 6 \times s \times D_1 \times l_e^2 + 1{,}5 + 0{,}05L$ cm^3
(7) Reverse frames in bracket floors	Modulus	$Z = 5{,}5 \times s \times h \times l_e^2 + 1{,}5 + 0{,}05L$ cm^3
Longitudinal framing system		
(8) Plate floors	Thickness	$t = 0{,}009d_f + 1$ mm
(6) Tanktop longitudinal	Modulus	$Z = 5{,}5 \times s \times h \times l_e^2 + 1{,}5 + 0{,}05L$ cm^3

Symbols

L, D, T, S, s, t and *Z* are as defined in 1.4.1
D_1 = *D* but need not be taken greater than *T* + 0,4 m
d_f = depth of bottom in way of centre girder, in mm
h = load head, which is to be taken as the greater of h_4 or h_5, in metres
h_4 = tank head, in metres, as defined in Ch 3,4
h_5 = distance, in metres, from mid point of span to the deck at side or to a point *T* + 0,4 m above the baseline, whichever is the lesser, but is to be taken as not less than 1 m
l_e = as defined in 1.4.1, but is to be taken as not less than 1,5 m . Struts are not considered as effective supports for the definition of l_e
l_b the width of the double bottom, in metres, and is normally the breadth of the ship. If longitudinal bulkheads or equivalent support is provided, an equivalent breadth may be used, but this should be not less than 0,8*B*
t_1 = thickness of inner bottom plating or bottom plating, whichever is the lesser, in mm

NOTE
The thickness of plating forming the double bottom structure is to be not less than:
5 mm for dry tanks and oil tanks
5,5 mm for water ballast tanks.

3.4 Single bottom – Longitudinal framing

3.4.1 Longitudinals are to be supported by transverses spaced not more than 3,5 m apart. The transverses are to be supported by a primary centreline girder or a centreline bulkhead. Tripping brackets connecting transverse to longitudinal are to be fitted between the centreline girder and shell at intervals not exceeding 3,5 m. The centreline girder may be omitted, provided the scantlings of the transverses are suitable for a span from side to side of the ship, and tripping brackets are fitted about 3,5 m or 20*b* m apart, whichever is the lesser, where *b* is the width in metres of the face plate of the transverse. Longitudinals are to be determined from Table 5.4.1. The scantlings of the centreline girder and bottom transverses are to be determined from Table 5.3.1.

3.5 Double bottoms

3.5.1 Where a double bottom is fitted, the space should be accessible. The minimum depth of the centre girder and the thickness of the centre girder and inner bottom plating are to comply with Table 5.3.2.

3.5.2 Plate floors in a transverse framing system are generally to be fitted at every frame and the scantlings are to comply with the requirements of Table 5.3.2. Vertical stiffeners having a depth of 80d_f mm are to be fitted to the floors and spaced not more than 2,5 m apart. The ends of these stiffeners may be sniped. Alternatively, bracket floors may be fitted, *see* Fig. 5.3.2, in which case the spacing of the plate floors is not to exceed 2,5 m.

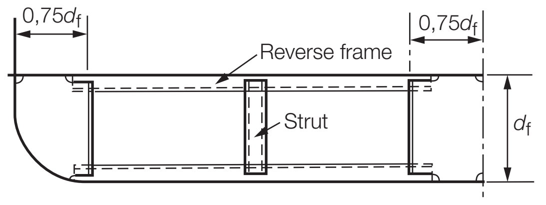


Fig. 5.3.2 Bracket floor

3.5.3 Where bracket floors are fitted the unsupported span of bottom frames and reverse frames is not to exceed 2,5 m. Struts may be fitted to reduce the unsupported span. If a strut is fitted at approximately half-span, the modulus of bottom and reverse frames may be reduced by 50 per cent. Struts are to comply with the requirements of Table 5.3.2. Watertight or plate floors are to be fitted below or in the vicinity of watertight bulkheads.

3.5.4 Where a longitudinal framing system is adopted in a double bottom, the scantlings of tank top longitudinals and plate floors are to comply with the requirements given in Table 5.3.2. Vertical stiffeners having a depth not less than 50 mm are to be fitted to the floors at every fourth longitudinal. The plate floors are to be spaced not more than 3,5 m apart. The centre girder may require to be stiffened when the height of the bottom is excessive. If a strut is fitted at approximately half-span the modulus of bottom and tank top longitudinals may be reduced by 50 per cent. Struts are to comply with the requirements of Table 5.3.2.

3.6 Swim end forward

3.6.1 Where a longitudinal framing system is adopted, the transverses or floors supporting longitudinals are to be spaced not more than 2,5 m apart, and the moduli of longitudinals and transverses are to be increased by 40 per cent.

3.6.2 Where a transverse framing system is adopted in swim ends, the modulus of plate floors is to be increased by 40 per cent.

3.6.3 The draught for calculation of the structural members may be taken as the actual draught in way of the respective member.

3.6.4 For rake plating, *see* 2.4.6.

■ *Section 4*
Shell envelope framing

4.1 General

4.1.1 Requirements are given in this Section for both longitudinal and transverse framing systems. Where longitudinal framing is adopted in the midship region it is to be carried forward and aft to at least the fore end and aft end of the cargo space, including cofferdams in case of tankers.

4.1.2 For frame spacings, *see* Ch 3,2.7.

4.2 Shell framing

4.2.1 The scantlings of side frames in the forward and aft regions are to comply with the requirements given in Table 5.4.1.

4.2.2 The scantlings of the frames are based on end connections in accordance with Ch 10,3. Where brackets, having arm lengths differing from the standard, are fitted, the frame modulus is to be corrected in accordance with Ch 10,3.7.

4.2.3 Where due to the shape of the vessel at the ends, the distance between frames measured along the shell exceeds the frame spacing, the scantlings, of side shell plating and supporting framing structure are to be based on the frame spacing as measured along the shell, alternatively intermediate frames may be fitted; or the frame spacing decreased.

4.2.4 The angle between the frame web and the shell plating is to be not less than 50°. Where this angle varies between 70° and 50°, the required modulus of the frame is to be corrected as per Ch 3,3.2.

4.2.5 In ships where the angle between the frame web and the shell plating would become less than 50°, the transverse framing, together with attached floors and beams, is to be inclined at an angle to the centreline of ship so that the frames lie as near normal to the shell plating as possible.

4.2.6 Where due to the curvature or slope of the shell panel the actual span of the frame measured along the shell is five per cent more than the vertical framing depth as per Fig. 5.4.1, the modulus of the frame is to be proportionally increased taking into consideration the shape of the frame.

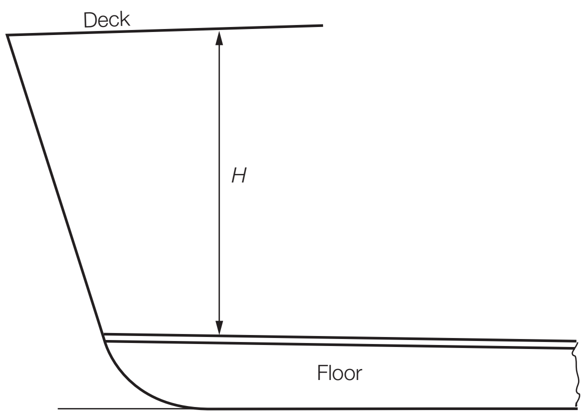


Fig. 5.4.1 Framing depth

Table 5.4.1 Shell frames and longitudinals forward and aft

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Frames clear of tanks	$Z_1 = 1{,}2D_1 \times s\,(2{,}5H^2 + 0{,}03B^2 + 6)$	$I = 3{,}2H\,Z_1$
(2) Frames in way of oil fuel or water tanks	The greater of the following: (a) $Z_2 = Z_1$ (b) Z_2 = as required by Chapter 7	$I = 3{,}2H\,Z_2$
(3) Bottom and side shell longitudinals clear of tanks	$Z_3 = 6 \times s \times h_5 \times l_e^2 + 1{,}5 + 0{,}05L$	$I = 3{,}2l_e\,Z_3$
(4) Bottom and side shell longitudinals in way of tanks	The greater of the following: (a) $Z_4 = Z_3$ (b) Z_4 = as required by Chapter 7	$I = 3{,}2l_e\,Z_3$
Symbols		
L, B, D, T, s, Z and I are as defined in 1.4.1 D_1 = D but need not be taken greater than T + 0,4 m H = vertical framing depth, in metres, from the top edge of floor or tanktop, to the deck at side as shown in Fig. 5.4.1, *see also* Note 1, but is to be taken as not less than 1,2 m h_5 = distance, in metres, from mid-point of span to the deck at side or to a point T + 0,4 m above the baseline, whichever is the lesser, but is to be taken as not less than 1 m l_e = as defined in 1.4.1 but is to be taken as not less than 1,5 m		
NOTES 1. Where frames are supported by fully effective horizontal stringers, these may be considered as decks for the purpose of determining H. 2. The web depth of frames is to be not less than 45 mm.		

4.3 Shell longitudinals

4.3.1 The scantlings of bottom and side shell longitudinals are to comply with the requirements given in Table 5.4.1.

4.3.2 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and so far as necessary, direct continuity of longitudinal strength, *see also* Ch 10,3.

4.4 Web frames and side transverses

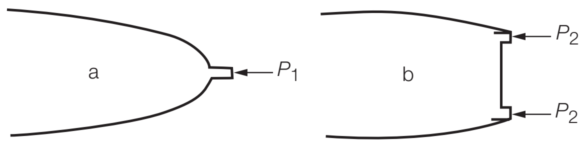
4.4.1 Web frames are, in general, to be fitted in a transverse framing system, and the scantlings are to comply with the requirements of Table 5.4.2.

4.4.2 The spacing of the web frames in a transverse framing system should not exceed 10 frame spaces, but the web frames may be omitted, provided the overall strength is maintained.

4.4.3 The side transverses in a longitudinal framing system are to be spaced not more than 3,5 m apart and the scantlings are to comply with the requirements of Table 5.4.2.

4.4.4 Frames are to be reinforced in way of hatch end beams and deck transverses, and the section modulus should be not less than 0,4 times the section modulus of the deck transverse.

4.4.5 The web thickness, stiffening arrangement and end connections of side transverses and web frames are to be in accordance with the requirements of Ch 10,4.



$$P_1 = \frac{0{,}015P_p \times L}{B} + 0{,}0136P_p \text{ tonnes}$$

$$P_2 = \frac{0{,}0098P_p \times L}{B} + 0{,}0136P_p \text{ tonnes}$$

$$\left(P = \frac{0{,}011 \times H_p \times L}{B} + 0{,}01H_p \text{ tonnes}\right)$$

$$\left(P = \frac{0{,}0072 \times H_p \times L}{B} + 0{,}01H_p \text{ tonnes}\right)$$

P_p, H_p, L and B are defined in 1.4.1

Fig. 5.4.2 Loads on stem for pushing purposes

4.5 Stringers

4.5.1 On ships frequently berthing under adverse conditions and where the span of the frames exceeds 2,5 m, an effective stringer is to be fitted in a suitable position.

4.5.2 The scantlings of side stringers if fitted, are to be determined from Table 5.4.2.

4.6 Stem arrangement for pushing purposes

4.6.1 The structural arrangements are to be such that the stem is adequately supported and integrated into the fore peak structure.

Table 5.4.2 Web frames, side transverses and stringers forward and aft

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Web frames in a transverse framing system	$Z = 2{,}5 \times (2 + n) \times s \times D_2{}^3$	$I = 2{,}5 D_2 Z$
(2) Side transverses in a longitudinal framing system	$Z = 7 \times S \times D_2{}^3$	$I = 2{,}5 D_2 Z$
(3) Side stringers (fully effective)	$Z = 8 \times S \times h \times l_e{}^2$	$I = 2{,}5 l_e Z$
Symbols		
D, T, S, s, Z and *I* are as defined in 1.4.1 D_2 = *D* but need not be taken greater than 1,5 x the effective span of the stiffening member l_e = as defined in 1.4.1 but is to be taken as not less than 1,5 m n = number of frame spaces between the web frames or equivalent structure h = load head, which is to be taken as h_4 or h_5 whichever is the greater, in metres h_4 = tank head, in metres, as defined in Ch 3,4 h_5 = distance, in metres, from mid point of span to the deck at side or to a point T + 0,4 m above the baseline, whichever is the lesser, with a minimum of 1 m		
NOTES 1. The web depth of side transverses is to be not less than twice the depth of the slot for the longitudinal. 2. The web depth of fully effective stringers is to be not less than twice the depth of the slot for the frames.		

4.6.2 The structure of the stem and the fore peak in way is to be calculated using horizontal loads P_1 or P_2 on the stem as shown in Fig. 5.4.2(a) and (b). The maximum compressive stresses in this structure are not to exceed 78,4 N/mm^2 (800 kg/cm^2).

■ *Section 5* Deck structure

5.1 General

5.1.1 Where the deck, outside the line of openings, is longitudinally framed in the midship region, this system of framing is to be carried as far forward and aft as possible.

5.2 Deck stiffening

5.2.1 The scantlings of deck beams and longitudinals are to comply with the requirements of Table 5.5.1.

5.2.2 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and so far as necessary, direct continuity of longitudinal strength.

5.2.3 End connections of beams are to be in accordance with the requirements of Ch 10,3.

5.3 Deck supporting structure

5.3.1 Girders and transverses supporting beams and deck longitudinals in the fore ship and aft ship regions, are to comply with the requirements of Table 5.5.2. In general, transverses, webs or frames of increased scantlings, *see* 4.4, are to be arranged in way of deck transverses and are to be in line with the floors, where practicable.

5.3.2 Transverses supporting deck longitudinals are to be spaced not more than 3,5 m apart.

5.3.3 The web thickness, stiffening arrangements and end connections of primary supporting members are to be in accordance with Ch 10,4.

Table 5.5.1 Deck beams and longitudinals forward and aft

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Transverse beams	$Z = 4{,}3 \times s \times h_1 \times l_e{}^2 + 1{,}5 + 0{,}05L$	—
(2) Longitudinals	$Z = 4{,}3 \times s \times h_1 \times l_e{}^2 + 1{,}5 + 0{,}05L$	—
(3) In way of the crown of a tank	Z = as required in Chapter 7	$I = 2{,}3 l_e Z$
Symbols		
L, s, Z and *I* are as defined in 1.4.1 l_e = as defined in 1.4.1 but to be taken as not less than 2 m h_1 = head, in metres, as defined in Ch 3,4		
NOTE The web depth of beams is to be not less than 45 mm.		

Table 5.5.2 Deck supporting structure fore and aft

Item	Parameter	Requirement
Girders and transverses in dry spaces, *see* Note	Modulus	$Z = 4{,}75 \times h_1 \times S \times l_e^2$ cm^3
	Inertia	$I = 2{,}3 l_e Z$ cm^4
Pillars in dry spaces, *see* Note	Cross-sectional area of all types of pillar	$A_p = \dfrac{P}{1{,}26 - 4{,}2\frac{l}{r}}$ cm^2
	Minimum wall thickness of hollow pillars	The greater of (a) and (b): (a) $t = 0{,}033 d_p$ for tubular pillars, mm (a) $t = 0{,}056 b$ for square pillars, mm (b) $t = 5$ mm
Symbols		
S, Z, I and t are as defined in 1.4.1 b = breadth of side of a hollow rectangular pillar, in mm d_p = mean diameter of tubular pillars, in mm h_1 = head, in metres, as defined in Ch 3,4 l = overall length of pillar, in metres l_e = as defined in 1.4.1, but not less than 2 m r = least radius of gyration of pillar cross-section, in mm, and may be taken as: $r = 10\sqrt{\dfrac{I_p}{A_p}}$ A_p = cross-sectional area of pillar, in cm^2 I_p = least moment of inertia of cross-section, in cm^4 P = load supported by the pillar, in tonne-f		
NOTE For deck supporting structure in tanks, *see also* Chapter 7.		

5.3.4 Where a girder or transverse is subjected to concentrated loads, such as pillars or winch seatings, the scantlings are to be determined by direct calculation.

5.3.5 Pillars are to comply with the requirements of Table 5.5.2.

5.3.6 Pillars are to be fitted in the same vertical line wherever possible, and are to be attached at their heads by efficient brackets, in order to transmit the load effectively. Doubling plates are generally to be fitted under the heels of pillars. The pillars are to have a bearing fit.

5.3.7 The structure in single or double bottoms in way of pillars is to be suitable to support the load imposed on this structure by the pillars.

5.3.8 Where bulkhead stiffeners support pillars, girders or transverses, the stiffeners, in association with a width of plating equal to half the stiffener spacing, should comply with the requirements of Table 5.5.2 for pillars.

■ *Section 6*
Fore peak structure

6.1 General

6.1.1 The requirements in this Section apply to the arrangements of primary structure supporting the peak framing and the scantlings of the collision bulkhead. Furthermore, requirements for wash bulkheads and perforated flats are given.

6.2 Bottom structure

6.2.1 The bottom of the peak space is generally to be transversely framed with arrangements and scantlings as detailed in 3.3.

6.2.2 Where a swim end is arranged in the fore ship and the bottom is longitudinally framed, the longitudinal framing may be extended in the fore peak. The arrangements and scantlings are to be as detailed in 3.6 and 4.3, but the draught for calculation of the longitudinals and transverses may be taken as the actual draught in way of the member.

Table 5.6.1 Fore peak structure

Item	Parameter	Requirement
(1) Collision bulkhead	Plating thickness Stiffener modulus	The greatest of: $t = 4 \times s \times \sqrt{h_5} + 1{,}5$ mm $t = 5$ mm $t = 5{,}5$ mm for water ballast tanks $Z = 4{,}3 \times s \times l_{e1}^2 \times h_5 + 4$ cm^3
(2) Perforated flats in void spaces	Plating thickness Stiffener modulus	The greater of: $t = 7s + 0{,}5$ mm $t = 5$ mm $Z = 3{,}5 \times s \times l_{e1}^2 + 3$ cm^3
(3) Wash bulkheads and perforated flats in tanks	Plating thickness Stiffener modulus	The greater of: $t = 7s + 1$ mm $t = 5$ mm $Z = 3{,}5 \times s \times l_{e1}^2 + 4$ cm^3
Symbols		
l_e, s, Z and t are as defined in 1.4.1 l_{e1} = l_e but should be taken as not less than 2 m h_5 = load height, in metres, measured vertically as follows: (i) for plating – the distance from the lower edge of the plate to a point 1 m above the tip of the bulkheads at side, or to the top of the overflow, whichever is the greater (ii) for stiffeners – the distance from the middle of the effective length to a point 1 m above the top of the bulkhead at side, or to the top of overflow, whichever is the greater		

6.3 Side structure

6.3.1 The framing in the fore peak may be either transverse or longitudinal but should generally be the same system as the framing aft of the fore peak bulkhead. The scantlings and arrangements of transverse and longitudinal framing are to be as detailed in 4.2 and 4.3 respectively.

6.3.2 Transverses supporting side longitudinals are to be fitted not more than 2,5 m apart. Suitable transverses or deep beams are to be arranged at the deck of the fore peak to provide end rigidity to the side transverses.

6.4 Wash bulkheads and perforated flats

6.4.1 Wash bulkheads to support deck beams and/or floors may be fitted in the fore peak and in tanks extending from side to side.

6.4.2 Perforated flats may be fitted in lieu of stringers on shell and bulkheads, *see* 4.5.

6.4.3 Wash bulkheads and perforated flats are generally to have an area of perforation between 5 and 10 per cent of their area.

6.4.4 The scantlings of wash bulkheads and perforated flats are to be determined from Table 5.6.1.

6.5 Collision bulkhead

6.5.1 The position and height of the collision bulkhead is to be in accordance with the requirements of Chapter 7.

6.5.2 The scantlings are to be determined from Table 5.6.1. End connections of stiffeners are to be in accordance with Ch 10,3.

6.5.3 Doors, manholes, permanent access openings and ventilation ducts are not permitted in the collision bulkhead below the uppermost continuous deck.

■ *Section 7* Aft peak structure

7.1 General

7.1.1 The requirements given in this Section apply to the arrangements of primary structure supporting the peak framing, the scantlings of the bottom structure, framing, aft peak bulkhead, transom and swim end.

7.2 Bottom structure

7.2.1 The bottom of the peak space is generally to be transversely framed with arrangements and scantlings as detailed in 3.3.

7.2.2 When the ship is self-propelled, the thickness of the floors in the aft peak is to be increased by 15 per cent and the floors are to be suitably stiffened.

7.2.3 Where the bottom in the aft peak is longitudinally framed, the arrangements and scantlings are to be as detailed in sub-Section 4.3; additional bottom transverses are to be fitted in way of rudder posts, propeller posts and shaft brackets if fitted.

7.3 Side structure

7.3.1 The framing in the aft peak may be either transverse or longitudinal. The scantlings and arrangements of the framing are to be as required in 4.2 and 4.3 respectively.

7.4 Aft peak bulkhead

7.4.1 The position and height of the aft peak bulkhead and the scantlings are to be in accordance with the requirements of Chapter 7. The plating is to be locally increased in way of the sterntube gland.

7.5 Transom

7.5.1 Where a transom is arranged in the aft ship, the scantlings and arrangements of plating and stiffening are to be as detailed in Sections 2 and 4 respectively.

7.6 Swim end aft

7.6.1 The draught for calculation of the structural members may be taken as the actual draught in way of the respective member.

7.7 Stern arrangement for pushing purposes

7.7.1 Where the ship is intended to be pushed, the stern arrangement is to comply with the requirements of 4.6 for the stem arrangement. The forces P_1 or P_2 are to be determined applying a value of P_p (H_p) based on the intended service conditions.

■ *Section 8* Sternframes and appendages

8.1 General

8.1.1 Sternframes, propeller bosses and shaft brackets may be constructed of forged or cast steel, or may be fabricated from plate.

8.1.2 Forgings and castings are to comply with the requirements of Chapters 5 and 4 of LR's Rules for Materials respectively.

8.1.3 Cast stern frames, rudder horns and solepieces are to be manufactured from special grade material, *see* Ch 4,2 of the Rules for Materials.

8.1.4 Sternframes, shaft brackets, etc., are to be effectively integrated into the ship's structure and their design is to be such as to facilitate this.

8.2 Sternframes

8.2.1 The scantlings of sternframes are to be determined from Table 5.8.1. The scantlings for sternframe configurations other than described in this Section, and for cast steel sternframes, will be specially considered, but the strength is to be at least equivalent to a fabricated sternframe.

8.2.2 Fabricated sternframes are to be strengthened by transverse webs, spaced not more than 700 mm apart.

8.2.3 Solepieces are to be carried well forward and efficiently scarfed into the keel. Special care is to be taken to avoid any stress-raising details at the point where the solepiece enters the shell plating.

8.2.4 Stern posts and rudder stock lower bearings are to be connected to floors of which the thickness is to be increased by 2 mm, above the thickness required by 7.2.

8.3 Propeller shaft bossing

8.3.1 The finished thickness of the propeller boss in single and twin screw ships is to comply with Table 5.8.1. The length of the boss is to be adequate to accommodate the aftermost shaft bearing, and to allow for a proper connection to the propeller post or shaft brackets.

8.4 Shaft brackets

8.4.1 Where the propeller shafting is exposed for some distance clear of the hull, it is to be supported adjacent to the propeller by independent brackets having two arms. The use of single arm brackets will receive special consideration.

8.4.2 Shaft brackets are to be designed to ensure a satisfactory connection to the internal hull structure; hard spots are to be avoided. Bracket arms are generally to be carried through the shell plating, which is to be locally increased in thickness, *see* 2.4.5. The connection of the arms to the bearing boss and shell plating is to be by full penetration welding.

8.4.3 The scantlings of double arm shaft brackets are to comply with the requirements of Table 5.8.1. The scantlings of single arm brackets will be specially considered.

Table 5.8.1 Sternframes

Item	Parameter	Requirement	
		Forged or roll steel	Fabricated steel
(1) Propeller posts	A	for $L \leq 60$ m : $\left(10 + \frac{L}{2}\right) 0{,}8T$ cm^2	—
	A	for $L > 60$ m : $32T$ cm^2	—
	t_1	—	$12 + 0{,}11L$ mm
	r	—	$18 + 0{,}17L$ mm
	l	—	$150\sqrt{T}$ mm
	w	—	$100\sqrt{T}$ mm
	t_w	—	$5 + 0{,}05L$ mm
(2) Sternpost in twin screw ships and non-propelled ships	A	for $L \leq 60$ m : $\left(10 + \frac{L}{2}\right) 0{,}7T$ cm^2	—
	A	for $L > 60$ m : $28T$ cm^2	—
	t_1	—	$8 + 0{,}07L$ mm
	r	—	$12 + 0{,}11L$ mm
	l	—	$150\sqrt{T}$ mm
	w	—	$100\sqrt{T}$ mm
	t_w	—	$5 + 0{,}05L$ mm
(3) Propeller shaft boss	t_b	$0{,}25D_{ts} + 10$ mm	
(4) Solepieces (open type sternframe) supporting the lower rudder pintle	Z_T	$c.Ar(V + 5{,}6)^2 \times (a/b - 0{,}15) \times 0{,}95\ a/b$ cm^3 *see* Note 4	
	Z_V	$0{,}5Z_T$ cm^3	
(5) Double arm shaft brackets	Z_T	$(16 \times 10^{-6} \times D_{ts}{}^3) + 8$ cm^3	
	N	$\geq 0{,}05e$ mm	
	M:N	between 2,5 and 5	

Symbols

L and T are as defined in 1.4.1

- a, b, c = distances, in metres, as shown in Fig. 5.8.2
- e = length of the longest shaft bracket strut, in mm
- t_b = finished thickness of boss, in mm
- t_1, r, l, w, t_w = scantlings of stern post, in mm, as shown in Fig. 5.8.1
- A = cross-sectional area of forged or rolled steel stern post, in cm^2
- A_r = total rudder area, in m^2
- D_{ts} = diameter of tail shaft in way of the boss, in mm
- M = the breadth of the shaft bracket strut, in mm, for e, M and N, *see also* Fig. 5.8.3
- N = the thickness of the shaft bracket strut, in mm
- V = maximum service speed with the ship in loaded condition, in km/h
- Z_T = section modulus against transverse bending, in cm^3
- Z_V = section modulus against vertical bending, in cm^3

NOTES
1. In fabricated sternframes the connection of the propeller post to the boss is to be by full penetration welding.
2. Solepieces supporting movable nozzles will be specially considered.
3. The support of a solepiece by a fixed nozzle arrangement will be specially considered.
4. The length 'a' of the solepiece should be taken as not less than $0{,}4b$ in the formula for Z_T.

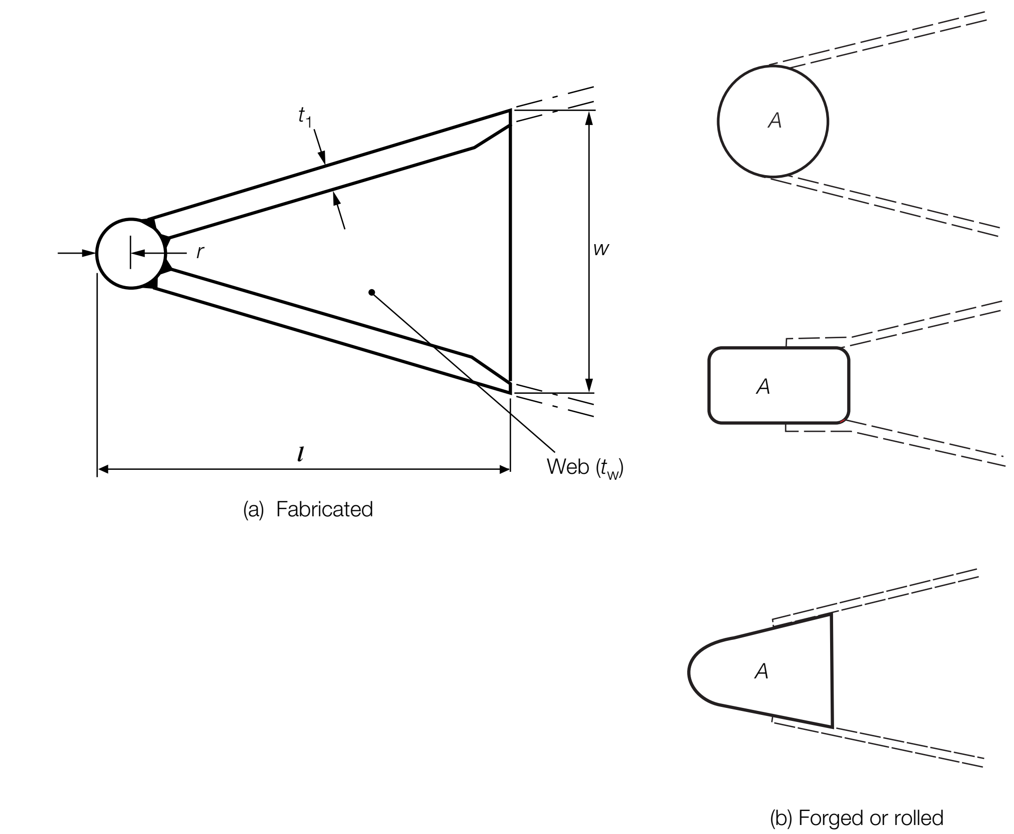


Fig. 5.8.1 Propeller posts

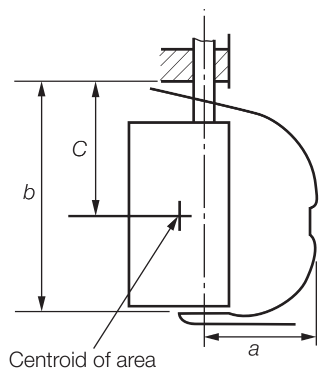


Fig. 5.8.2 Open sternframe

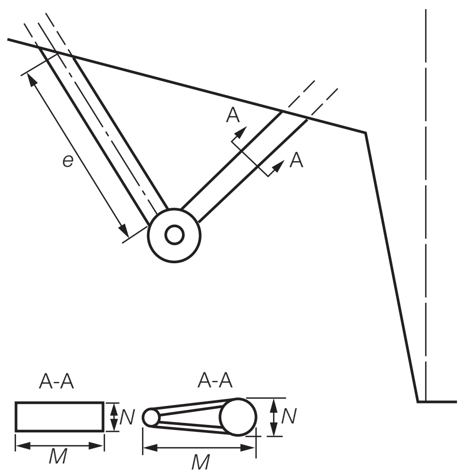


Fig. 5.8.3 Shaft brackets

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all ship types detailed in Part 4, with propulsion machinery and/or auxiliary machinery situated in a machinery space. Only the requirements particular to machinery spaces, including protected machinery casings and engine seatings, are given. For other scantlings and arrangement requirements, *see* Chapter 5 and the relevant Chapter in Part 4 for the particular ship type concerned.

1.2 Structural configuration and continuity

1.2.1 The Rules provide for both longitudinal and transverse framing systems or a combination of both.

1.2.2 Where a machinery space is situated aft, and longitudinal bulkheads terminate at or in the machinery space, suitable taper brackets are to be provided at the ends of the bulkheads. Suitable scarfing arrangements are to be provided where a longitudinal framing system terminates at or in the machinery space.

1.2.3 Where a machinery space is situated amidships and the shell and deck outside the line of openings are longitudinally framed, this system of framing is also to be adopted in the machinery space. Longitudinal bulkheads, if fitted, are generally to be carried through the machinery space. Where structure which contributes to the main longitudinal strength of the ship is discontinued in way of a machinery space, suitable compensation and scarfing arrangements are to be provided.

1.3 Symbols and definitions

1.3.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D and *T* are as defined in Ch 1,6.1

s = spacing, of secondary stiffeners, i.e. frames or beams, in metres

t = thickness of plating, in mm

I = inertia of stiffening member, in cm^4, *see* Ch 3,3.2

S = spacing or mean spacing of primary members, in metres

Z = section modulus of stiffening member, in cm^3, *see* Ch 3,3.2.

■ *Section 2* Deck structure

2.1 Strength deck – Plating

2.1.1 Where a machinery space is situated aft, the deck plating thickness is to be as required in Ch 5,2.6. The corners of deck openings are to be of suitable shape and design to minimize stress concentrations.

2.1.2 Where a machinery space is situated amidships and large openings are provided in the strength deck, the thickness of the deck plating abreast the openings may require to be increased in thickness above that required in the relevant ship type Chapter in Part 4, in order to maintain the strength of the hull girder.

2.2 Lower deck – Plating

2.2.1 The plating of lower decks and flats is to comply with the requirements of Ch 5,2.6 or the relevant ship type Chapter in Part 4. The thickness of platforms on which auxiliary engines are placed, is to be increased locally by 1 mm.

2.3 Deck stiffening

2.3.1 The section modulus of main deck beams and longitudinals in way of machinery spaces is to be 20 per cent greater than that required by Ch 5,5.2 or in the relevant ship type Chapter in Part 4, but for decks on which auxiliary engines are placed, a further increase in way of 20 per cent is required, *see also* 5.3.1.

2.4 Deck supporting structure

2.4.1 In addition to the longitudinal girders and transverses, fitted to support the deck structure, deep beams are to be fitted at the fore and aft end of engine casings. Longitudinal girders may require to be fitted in line with the sides of casings. The depth of these deep beams and girders is to be at least twice the depth of the deck beams or longitudinals.

Section 3
Side shell structure

3.1 Primary structure

3.1.1 A transverse framing system is to be additionally reinforced by web frames fitted five frame spaces apart. Where a longitudinal framing system is adopted, the spacing of the transverses is not to exceed 2,5 m.

3.1.2 The scantlings of web frames and transverses are to be as required by Table 6.3.1.

Table 6.3.1 Web frames and side transverses in machinery spaces

Location	Modulus, in cm^3	Inertia, in cm^4
(1) Web frames in a transverse framing system	$Z = 3,5 \times (1,5 + n) \times s \times D_2{}^3$	$I = 2,5 D_2 Z$
(2) Side transverses in a longitudinal framing system	$Z = 8 \times S \times D_2{}^3$	$I = 2,5 D_2 Z$
Symbols		
D, S, s and *Z* are as defined in 1.3.1 n = number of frame spaces between the web frames or equivalent structure D_2 = *D,* but need not be taken greater than 1,5 times the effective span of the stiffening member		
NOTE The web depth of side transverses is to be not less than twice the depth of the slot for the longitudinal.		

Section 4
Single and double bottom structure

4.1 General

4.1.1 This Section applies to transversely and longitudinally framed bottoms.

4.1.2 Where a machinery space is situated in the aft ship, the bottom is generally to be transversely framed. Elsewhere the transverse or longitudinal framing may be adopted.

4.1.3 Care is to be taken that the rigidity of the bottom structure is not impaired by discontinuities such as recesses, lightening holes and large drain holes.

4.1.4 Floors and girders are not to be flanged, but provided with welded face bars.

4.2 Bottom construction

4.2.1 Where the bottom is transversely framed, plate floors are to be fitted at every frame and the scantlings are to comply with the requirements of Table 6.4.1. The thickness of the floors in way of the engine seating is also to comply with the requirements of 5.2.

4.2.2 Where the bottom amidships is longitudinally framed, the bottom transverses or plate floors in a double bottom abreast the engine seating are to be spaced not more than 1,8 m apart and the thickness is to comply with the requirements of Table 6.4.1. In way of the engine seating, floors are to be fitted at every frame and the thickness is to comply with 5.2, *see also* Fig. 6.4.1.

4.2.3 The transverse strength of the bottom is also to be maintained when the bottom construction is recessed under the engines.

4.2.4 The centre girder, if required, may be omitted where the engine girders are situated less than 1,5 m from the centreline of the ship, but a docking girder should generally be fitted. Side girders are to be fitted when normally required in the same position.

4.3 Bottom plating

4.3.1 The bottom plating in machinery spaces is to be as required in Chapter 5 or as in the relevant ship type Chapter in Part 4, but the plating in way of the engine seatings is to be not less than required in Table 6.4.1. When the thickness of the bottom plating is to be increased to meet this requirement, the increased plating is to extend for at least two frame spaces beyond the full length of the engine seating and for 1 m on either side of the seating girders.

Table 6.4.1 Bottom construction in the machinery space

Item	Parameter	Scantlings
Transverse framing system		
Floors (single bottom)	Web depth at centreline Modulus Web thickness	$d_f = 50l_f$ mm $Z = 7{,}2 \times D_1 \times s \times l_f^{\,2}$ cm^3 $t = 0{,}01d_f + 2$ mm
Floors (double bottom)	Web thickness	$t = 0{,}008d_f + 2$ mm
Longitudinal framing system		
Bottom transverses	Modulus Web thickness	$Z = 10 \times D_1 \times S \times l_e^{\,2}$ cm^3 $t = 0{,}01d_f + 2$ mm
Floors (double bottom)	Web thickness	$t = 0{,}01d_f + 2$ mm
Transverse and longitudinal framing system		
Bottom shell plating in way of engine seating	Minimum thickness	$t = 0{,}03A + 4{,}5$ mm
Symbols		
D, T, S, s and *Z* are as defined in 1.3.1 d_f = depth of floor at centreline, in mm l_e = span of bottom transverse, in metres l_f = span of the floor, in metres, and is normally the breadth of the ship measured on top of the floor under consideration. If longitudinal bulkheads or equivalent floor supports are provided, an equivalent breadth may be used, but this should be not less than 0,4*B* A = area of engine seating top plate, in cm^2, as required by Table 6.5.1 D_1 = *D,* but need not be taken greater than T + 0,4 m		

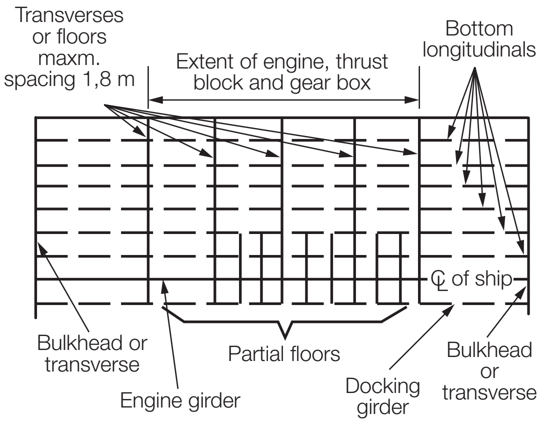


Fig. 6.4.1
Engine room bottom with longitudinal framing

4.4 Water inlets

4.4.1 Water inlets and other openings such as openings for cooler boxes are to have well rounded corners. The thickness of water inlet and cooler box plating is to be 2 mm greater as the adjacent shell plating, or 9 mm, whichever is the greater

■ *Section 5* Engine seatings

5.1 General

5.1.1 Main engines and thrust bearings are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the various gravitational, thrust, torque, dynamic and vibratory forces which may be imposed on them.

5.2 Seats for main propulsion oil engines

5.2.1 The seats are to be so designed that they distribute the forces from the engine(s) as uniformly as possible into the supporting structure. Longitudinal girders supporting the seatings are to be arranged in single or double bottoms, and should, in general, extend over the full length of the machinery space. The ends of the girders are to be scarfed into the bottom structure for at least two frame spaces. Adequate transverse brackets are to be arranged in line with floors, *see* Fig. 6.5.1. Small brackets may be required under the top plate in way of holding down bolts.

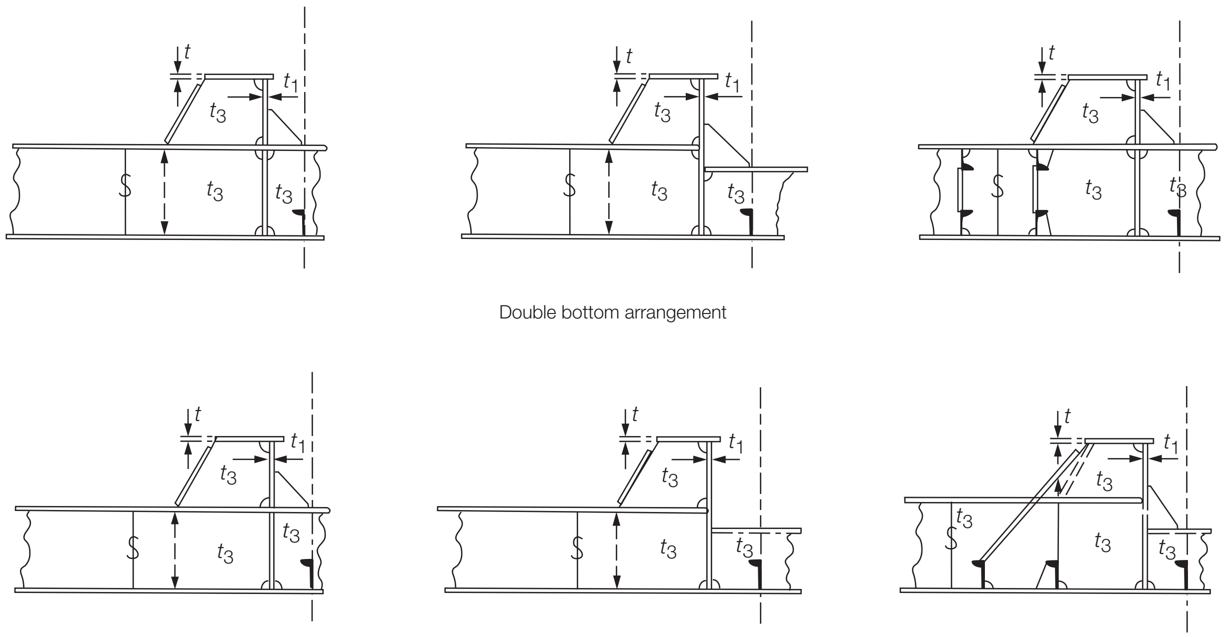


Fig. 6.5.1 Typical engine seatings

Table 6.5.1 Seats for oil engines

Item	Parameter	Scantlings
Top plates	Area for one top plate	$A = f\,(0{,}088P + 25)$ cm^2 ($A = f\,(0{,}065H + 25)$ cm^2)
	Minimum thickness	$t = 0{,}1A + 14$ mm
Girders under top plate	Web thickness	$t_1 = 0{,}043A + 7$ mm
Girders fore and aft of engine	Web thickness Face plate area	$t_2 = 0{,}01d_f + 2$ mm $A_1 = 0{,}1A + 4$ cm^2
Floors (in way of seating)	Web thickness	$t_3 = 0{,}02A + 6$ mm or as that required in Section 4, whichever is the greater
Symbols		
d_f = depth of girder, in mm f = 1,3 – 0,0003R, where R = rev/min of engine at maximum service speed t = minimum thickness of top plate, in mm t_1 = main engine girder thickness, in mm t_2 = thickness of girders in line with engine seating girders, fore and aft of the engine, in mm t_3 = thickness of floor plate in way of seating, in mm A = area of top plate for one side of seat, in cm^2 A_1 = area of girder face plate, in cm^2 P = power of one engine at maximum service speed, in kW (H = power of one engine at maximum service speed, in bhp)		

5.2.2 In determining the scantlings of seats for main propulsion oil engines, consideration is to be given to the general rigidity of the engine itself and to its design characteristics in regard to out of balance forces. As a general guide to designers, minimum scantlings are given in Table 6.5.1.

5.3 Seats for auxiliary machinery

5.3.1 Auxiliary machinery is to be secured to seatings of adequate scantlings, so arranged as to distribute the loads evenly into suitably designed supporting structure. For larger auxiliary machinery, the scantlings of Table 6.5.1 may be used as a guide.

5.4 Seats for boilers

5.4.1 Boiler bearers are to be of substantial construction and efficiently supported by the ship's structure, *see also* Pt 5, Ch 8,2.

■ *Section 6* Machinery casings and oil fuel tanks

6.1 Machinery casings

6.1.1 The scantlings and arrangements of exposed casings protecting machinery openings are to be in accordance with Ch 8,2.

6.1.2 The minimum scantlings of protected casings are to be in accordance with Table 6.6.1.

Table 6.6.1 Protected machinery casings

Item	Minimum scantlings
Plating	$t = 7s$ mm or $t + 3{,}5$ mm, whichever is the greater
Stiffeners	$Z = 15s + 4$ cm^3
Symbols	
Z, t and *s* are as defined in 1.3.1	
NOTE The depth of stiffeners is to be not less than 45 mm.	

6.1.3 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably increased.

6.1.4 Casing bulkheads are to be made gastight and the access doors are to be of a gastight self-closing type.

6.2 Oil fuel tanks

6.2.1 Oil tanks integral with the ship's structure in the machinery space are generally to comply with the requirements given in Chapter 7.

6.2.2 The scantlings of oil tanks not integral with the ship's structure are to comply with Pt 5, Ch 12,4.9.

6.2.3 Where a pipe is fitted in the bilge to facilitate the transition between the horizontally oriented bottom plating and the vertically oriented side shell plating and it passes through oil fuel tanks, small stoppers are to be fitted in the pipes to prevent the passage of fuel to adjacent tanks in case of leakage of the pipe. In this case, small plugs for draining and venting purposes of the individual pipe part contiguous to the fuel oil tanks are to be fitted.

■ *Section 7* Means of escape

7.1 General

7.1.1 In machinery spaces, boiler rooms or under-deck pump rooms, two means of escape are generally to be provided. A second means of escape may be dispensed with if:

(a) The total floor area (average length x average width at the level of floor plating) of subject space does not exceed 35 m^2 and

(b) The distance between each point where servicing or maintenance operations are carried out and the exit, or stairs providing access to the outside, is not greater than 5 metres.

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter cover the transverse, longitudinal and horizontal boundaries of watertight compartments and deep tanks. Requirements are also given for non-watertight bulkheads. For bulkheads in the cargo compartment space of tankers, *see* the individual ship type Chapters in Part 4.

1.1.2 The requirements of this Chapter apply to vertically stiffened bulkheads. They may also be applied to horizontally stiffened bulkheads provided that equivalent end support is fitted and alignment provided.

1.2 Number and disposition of bulkheads

1.2.1 All ships are to have a collision bulkhead, a watertight bulkhead at each end of the machinery space and an after peak bulkhead. In ships with the machinery space aft, the after peak bulkhead may form the after boundary of the machinery space. Where sterntubes are enclosed in a suitable watertight space, the after peak bulkhead may be omitted in ships as indicated in 1.4.1. Additional bulkheads are to be fitted to provide for sufficient transverse strength of the vessel.

1.2.2 The bulkheads in the holds should be spaced at reasonably uniform intervals. Where non-uniform spacing is unavoidable and the length of a hold is unusually great, the transverse strength of the ship is to be maintained by fitting web frames, increased framing, etc. Details are to be submitted for approval.

1.2.3 For subdivision requirements within the cargo tank region of tankers, *see* individual ship type Chapters in Part 4.

1.2.4 Where applicable, the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability of the National Authority of the country in which the ship is to operate or be registered.

1.3 Collision bulkhead

1.3.1 The collision bulkhead is to be positioned not less than 0,04*L* and not more than 0,1*L* from the F.P. Attention is also drawn to additional requirements of National or International Authorities, e.g. 'Inspection Regulations' of the C.C.N.R. Special designs or types of ships requiring another position, will be specially considered.

1.3.2 Doors, manholes, permanent access openings or ventilation ducts are not to be cut in the collision bulkhead below the uppermost continuous deck.

1.3.3 Any recesses or steps in collision bulkheads are to fall within the limits of bulkhead positions.

1.3.4 Oil fuel is not to be carried forward of the collision bulkhead.

1.4 After peak bulkhead

1.4.1 All ships are to have an after peak bulkhead generally enclosing the sterntube and the ruddertrunk in a watertight compartment. This after peak bulkhead need not be fitted on the following ships if the sterntube is enclosed in a suitable watertight space:

(a) Ships with a length *L* less than 25 m.
(b) Ships where the forward machinery space bulkhead is situated less than seven per cent from the after perpendicular (A.P.).
(c) Ships where the forward machinery space bulkhead is situated less than 25 per cent from the after perpendicular and where the maximum allowable draught is less than 0,4*D*.

In ships with two or more propellers where the bossing ends forward of the after peak bulkhead, the sterntubes are to be enclosed in a suitable watertight space.

1.5 Height of bulkheads

1.5.1 All bulkheads are to extend to the uppermost continuous deck. In ships with continuous coamings the transverse hold bulkheads are to extend to the top of the coaming and are to be suitably stiffened at their top edge.

1.6 Protection of tanks carrying oil fuel, lubricating oil, vegetable or similar oils

1.6.1 Cofferdams are required between each tank carrying:

(a) Oil fuel or lubricating oil;
(b) Feed water or fresh water; and
(c) Vegetable or similar edible oils.

However, cofferdams need not be fitted between oil fuel or lubricating oil double bottom tanks and deep tanks carrying (b) or (c) provided that the double bottom tanks are not interconnected with any tanks above.

1.6.2 Lubricating oil compartments are also to be separated by cofferdams from those carrying oil fuel. However these cofferdams need not be fitted provided that:

(a) Common boundaries of lubricating oil and oil fuel tanks have full penetration welds.
(b) The tanks are arranged such that the oil fuel tanks are not generally subjected to a head of oil in excess of that in the adjacent lubricating oil tanks.

1.6.3 Cofferdams are required between oil fuel double bottom tanks and deep tanks above when the doube bottom tank and side tanks are interconnected.

■ *Section 2* Scantlings of bulkheads

2.1 Watertight and deep tank bulkheads as indicated in 1.1.1

2.1.1 The scantlings of watertight and deep tank bulkheads are to comply with the requirements of Table 7.2.1. The scantlings of the collision bulkhead are to be in accordance with Ch 5,6.5. Where bulkhead stiffeners support deck girders, transverses or pillars over, they are also to comply with Table 7.2.3.

2.1.2 Stiffening members of horizontal bulkheads of tanks may be supported by girders or a system of girders and pillars.

2.1.3 Pillars in tanks are not to be of hollow construction and are to be bracketed at top and bottom. Scantlings and welding of the brackets are to take account of the maximum tensile force on the pillar.

2.1.4 End connections of stiffeners are to be in accordance with the requirements of Ch 10,3. Where stiffeners are not fitted with the required end brackets, the modulus of the stiffeners is to be increased in accordance with Ch 10,3.7.

2.1.5 Oil fuel carried in tanks is to have a flash point not less than 55°C. Where tanks are intended for liquid fuels of a special nature, the scantlings and arrangements will be considered in relation to the nature of the fuel, *see also* Pt 5, Ch 12,2.

Table 7.2.1 Watertight and deep tank bulkhead scantlings

Item and requirement	Watertight bulkheads	Deep tank bulkheads
(1) Plating thickness for plane and symmetrically corrugated bulkheads	The greater of the following: $t = 4w\sqrt{h_4} + 0{,}5$ mm or t = 4 mm, *see* Note 3	The greater of the following: $t = 4w\sqrt{\rho h_4} + a$ mm or t = 5 mm for oil tanks and fresh water tanks t = 5,5 mm for water ballast tanks, *see* Note 3
(2) Modulus of rolled and built stiffeners, swedges and symmetrical corrugations	$Z = 5 \times s \times l_e^2 \times h_4$ cm^3	$Z = 6 \times s \times l_e^2 \times h_4 \times \rho$ cm^3
(3) Stringers or webs supporting vertical or horizontal stiffening (a) Modulus (b) Inertia	$Z = 7 \times h_4 \times s \times l_e^2$ cm^3 —	$Z = 8{,}5 \times h_4 \times s \times l_e^2 \times \rho$ cm^3 $I = 2{,}5 \times Z \times l_e$ cm^4
(4) Pillars in tanks, cross-sectional	—	$A = 4{,}5 + 0{,}9P$ cm^2

Symbols

t = thickness of plating, in mm
Z = section modulus of stiffening member, in cm^3, *see* Ch 3,3.2
s = spacing of stiffeners, corrugations, girders or webs, in metres
l_e = effective length of stiffening member, in metres, *see* Ch 3,3.3
I = inertia of stiffening member, in cm^4, *see* Ch 3,3.2
ρ = specific gravity of liquid carried in the tank, but is to be taken as not less than 1
w = plate width, in metres, defined as follows:
(a) for plane bulkheads the spacing of stiffeners, in metres
(b) for corrugated bulkheads the width of flange (b) or web (c), in metres, whichever is the greater, *see* Fig. 3.3.3 in Ch 3,3
a = 1 mm for oil and fresh water tanks and 1,5 mm for water ballast tanks
h_4 = load head, in metres, measured vertically as follows, *see also* Fig. 7.2.1
(a) for watertight bulkhead plating – the distance from the lower edge of the plate to the top of the bulkhead
(b) for deep tank bulkhead plating – the distance from the lower edge of the plate to a point 1 m above the top of the tank, or to the top of the overflow, whichever is the greater
(c) for watertight stiffeners or girders, the distance from the middle of the effective length to the top of the bulkhead
(d) for deep tank bulkhead stiffeners or girders, the distance from the middle of the effective length to a point 1 m above the top of the tank, or to the top of the overflow, whichever is the greater
P = load supported by the pillars, in tonne f

NOTES
1. For rolled or built stiffeners with flanges for face plates, the web thickness is to be not less than $\frac{1}{60}$ of the web depth, whilst for flat bar stiffeners the web thickness is to be not less than $\frac{1}{16}$ of the web depth.
2. Additional requirements for corrugated bulkheads are given in Ch 3,3.2.
3. Bulkhead plating from the bottom to 0,1 m above ceiling in holds is to be at least 6 mm in thickness.

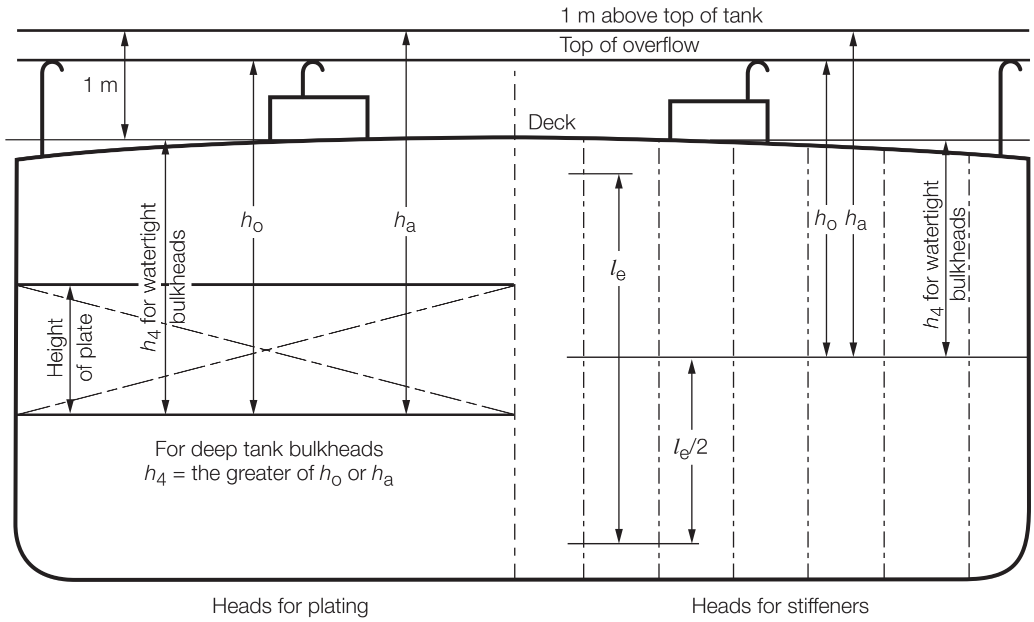


Fig. 7.2.1 Heads for watertight and deep tank bulkheads

2.1.6 If cargo is carried in a compartment adjacent to an oil fuel tank which may be heated, the compartment side of the bulkhead or deck is to be insulated, or equivalent arrangements provided.

2.1.7 Where watertight bulkhead stiffeners are cut in way of watertight doors, the opening is to be suitably framed and reinforced, and the adjacent stiffeners are to be increased in proportion to the greater spacing. Where the stiffener spacing is locally increased on account of watertight doors, the stiffeners at the sides of the doorways are also to be increased. Recesses in bulkheads are generally to be so stiffened as to provide strength and stiffness equivalent to the requirements for the bulkhead.

2.2 Non-watertight bulkheads

2.2.1 The scantlings of non-watertight bulkheads acting as hull supporting structure are to comply with the requirements of Table 7.2.2. Where the bulkhead stiffeners support deck girders, transverses or pillars over, they are also to comply with the requirements of Table 7.2.3.

Table 7.2.2 Non-watertight bulkheads

Parameter	Requirements
(1) Plating thickness for plane bulkheads	The greater of the following: $t = 4 \times s \times \sqrt{h_4}$ mm or $t = 3{,}5$ mm
(2) Modulus of rolled and built stiffeners and swedges	$Z = 4 \times s \times l_e^2 \times h_4 + 3$ cm^3
NOTE *See* Table 7.2.3 for symbols definition.	

Table 7.2.3 Bulkhead stiffeners supporting concentrated loads

Parameter	Requirements
(1) Cross-sectional area for rolled, built or swedged stiffeners, supporting girders, transverses, pillars or concentrated loads	$A = \dfrac{P}{1{,}26 - 4{,}2\dfrac{l}{r}}$ cm^2 *see* Note
(2) Width of effective plating included in the cross-sectional area	The lesser of the following $w = 80t$ mm or $w = 700s$ mm

Symbols

h_4 = load, head, in metres, as specified for watertight bulkheads in Table 7.2.1
l = overall length of stiffener, in metres, *see* Ch 3,3.2
l_e = effective length of stiffening member, in metres, *see* Ch 3,3.3
r = least radius of gyration of stiffener with effective plating, in mm, and is to be taken as: $= 10\sqrt{\dfrac{I_p}{A}}$
s = spacing of stiffeners, in metres, but not to exceed 1,10 m
t = thickness of plating, in mm
w = width of effective plating, in mm
A = cross-sectional area of stiffening member inclusive of effective plating, in cm^2
I_p = least moment of inertia of stiffener with effective plating, in cm^4
P = load supported by stiffener, in tonne-f
Z = section modulus of stiffening member, in cm^3, *see* Ch 3,3.2

NOTE
The depth of stiffeners supporting concentrated loads is to be not less than 75 mm.

2.3 Bulkheads in cargo spaces

2.3.1 Bulkheads in cargo holds which are regularly exposed to contact with grabs or falling cargo are to be efficiently protected or the scantlings increased in order to reduce damage.

Section 1
General

1.1 Application

1.1.1 This Chapter applies to all types of ships.

1.1.2 The scantlings of superstructures, deckhouses and exposed machinery casings are generally to comply with the following requirements, but increased scantlings may be required where the structure is subjected to loading in excess of Rule limits, *see* Chapter 3.

1.1.3 The term 'erection' is used in this Section to include superstructures, deckhouses and machinery casings, superstructures being erections extending to the ship's sides.

1.1.4 For scantlings of protected machinery casings, *see* Ch 6,6.

1.1.5 For requirements relating to companionways, doors, accesses and skylights, *see* Chapter 11.

1.2 Definition of tiers

1.2.1 The lowest, or first tier, is that which is directly situated on the deck to which the depth, D, is measured or on a superstructure of less than 1,80 m in height. The second tier is the next tier above the lowest tier and so on.

Section 2
Scantlings of erections

2.1 Superstructures

2.1.1 The scantlings of plating and framing and the type of end connections of the side structure are to be the same as for the shell in way.

2.1.2 The scantlings of plating and stiffening and the type of end connections of the end bulkheads are to be the same as for the end bulkheads of deckhouses, *see* Table 8.2.1 (and further references as per 2.2.1, 2.3.2, 2.4.1 and 2.6.2).

Table 8.2.1 Deckhouse scantlings

Item	Parameter	Requirements
Side and end bulkheads of lower tier	Plating: $t = 7{,}5s + 0{,}010L$ mm	Stiffeners: $Z = 14fs + 4$ cm^3 wherein $f = 1{,}25 - 0{,}005L$ *See* Notes 1 and 2
Side and end bulkheads of 2nd and 3rd tiers	Plating: The greater of: $t = 7{,}5s + 0{,}010L - 0{,}75$ mm $t = 3$ mm	Stiffeners: $Z = 14fs + 4$ cm^3 wherein $f = 1{,}25 - 0{,}005L$ *See* Notes 1 and 3
Decks (all tiers)	Plating: $t = 8{,}0s + 0{,}013L$ mm	Beams and longitudinals: $Z = 4sh_i l_b^2 + 4$ cm^3 *See* Note 4
	Non-exposed decks and top decks: $t = 8{,}0s$ mm	Girders and transverses: $Z = 4{,}5h_i S l_e^2 + 4$ cm^3 $I = 2{,}3\, l_e Z$ cm^4
Pillars, *see* Note 5	Cross-sectional area Minimum wall thickness of hollow pillars	$A_p = 4{,}5 + 0{,}875P$ cm^2 The greater of: (a) $t = 0{,}033d_b$ mm for tubular pillars $t = 0{,}056b$ mm for square pillars (b) $t = 5$ mm

Symbols

b = breadth of side of hollow square pillars, in mm
b_d = breadth or length of the deck panel supported, in metres
d_b = mean diameter of tubular pillars, in mm
f = factor
h_i = design head and is to be taken as 0,45 m for no load bearing weather and accommodation decks and 0,30 m for top decks and the relevant values for h_i from Table 3.4.1 for load bearing decks
l_b = span, in metres, of deck beam or longitudinals and is to be taken not less than 1,5 m
l_e = effective span, in metres, of girder or transverse as defined in Ch 3,3.3
s = spacing of stiffeners, beams or longitudinals, in metres
A_p = cross-sectional area of tubular or hollow square pillar, in cm^2
L = length of ship, in metres, as defined in Ch 1,6.1
P = load, in tonne-f, supported by the pillar and is to be taken as $P = 0{,}72Sb_d h_i$ tonne-f, to which the load exerted by superposed pillars is to be added
S = spacing or mean spacing of girders, transverses or pillars supporting them, in metres
t = thickness of plating, in mm
Z = section modulus of stiffening member, in cm^3, *see* Ch 3,3.2

NOTES
1. If the unsupported length of a stiffener exceeds 2,5 m the section modulus is to be suitably increased.
2. The section modulus of the stiffeners is to be increased by 15 per cent where a second tier house is fitted and by 30 per cent where also a third tier is also fitted.
3. The section modulus of the stiffeners of the second tier is to be increased by 15 per cent if a third tier house is fitted.
4. The depth of beams and longitudinals is to be not less than 45 mm.
5. The minimum diameter of hollow pillars is 50 mm. The minimum dimensions of hollow square pillars is 45 x 45 mm. Solid and fabricated pillars are to be of equivalent strength.

2.1.3 The scantlings of plating and stiffening and the type of end connections of the deck structure are to be the same as for the main deck in the respective position.

2.2 Deckhouses and exposed machinery casings bulkhead plating

2.2.1 The thickness, t, of exposed end and side bulkheads is to comply with the requirements of Table 8.2.1.

2.2.2 The thickness of load bearing internal bulkheads is to be not less than 3 mm in conjunction with suitable stiffening.

2.3 Stiffeners and their end connections

2.3.1 Stiffeners are to be fitted in line with deck beams or longitudinals.

2.3.2 The section modulus of stiffeners of end and side bulkheads is to be in accordance with Table 8.2.1.

2.3.3 The lower end of stiffeners of single tier deckhouses may be unattached. The upper end of stiffeners of all tiers is to be connected to the deck beams or longitudinals.

2.3.4 When a multiple tier erection is fitted, the lower end of the side bulkhead stiffeners is to be attached to the deck, except in the case of the uppermost tier.

2.4 Deck plating

2.4.1 The thickness of exposed and unexposed deck plating is to be in accordance with Table 8.2.1.

2.5 Deck stiffening

2.5.1 Deck beams and longitudinals are to have a section modulus in accordance with the requirements of Table 8.2.1.

2.5.2 The beams and longitudinals are to be connected to the bulkhead stiffeners.

2.6 Deck supporting structure

2.6.1 Decks are to be supported by suitably spaced girders or transverses and pillars.

2.6.2 The scantlings of girders, transverses and pillars are to comply with Table 8.2.1.

2.6.3 Effective support is to be fitted under the heel of pillars.

2.6.4 The girders and transverses are to be suitably connected to the bulkhead stiffening. The modulus of the bulkhead stiffeners bearing transverses is to be increased by 40 per cent. End connections are generally to comply with Ch 10,4.7.

2.7 Strengthening at sides and ends of erections

2.7.1 Web stiffeners or equivalent strengthening is to be arranged to support the sides of large erections.

2.7.2 Web stiffeners should be spaced about 10 m apart and are to be arranged in line with bulkheads or webs below.

2.7.3 Web stiffeners or equivalent strengthening is also to be fitted within erections that have erections above exceeding 5 m in length or, 0,1*L*, whichever is the greater.

2.7.4 Adequate support under the ends of erections is to be provided.

2.8 Erections in way of machinery spaces

2.8.1 If engines of high horsepower in relation to the size or type of ship are fitted, measures are to be taken to prevent undue vibration of the structure.

2.9 Erections contributing to hull strength

2.9.1 Where an effective superstructure, *see* Ch 3,3.4.2 or a deckhouse with a length of more than 0,2*L* is fitted and which is situated within the midship 0,5*L* region, the scantlings of deck plating and longitudinals of these erections may require to be increased.

■ *Section 3* Aluminium erections

3.1 Restrictions in application

3.1.1 Attention is drawn to the fact that National and International Statutory Requirements restrict the application of aluminium for certain types of ships.

3.2 Scantlings

3.2.1 Where an aluminium alloy complying with Chapter 8 of LR's Rules for Materials is used in the construction of erections, the scantlings of these erections are to be increased (relative to those required for steel construction) by the percentages given in Table 8.3.1.

Table 8.3.1 Percentage increase of scantlings

Item	Percentage increase
Fronts, sides, aft ends, unsheathed deck plating	20
Decks sheathed in accordance with Ch 2,3	10
Stiffeners and beams	70
Scantlings of small isolated houses	Nil

3.2.2 The thickness, t, of aluminium alloy members is to be not less than:

t = $2,5 + 0,022d_w$ mm, but need not exceed 10 mm

where

d_w = depth of section, in mm.

3.2.3 The minimum moment of inertia, I, of aluminium alloy stiffening members is to be not less than:

I = $5,25 Z l_1$ cm^4

where

l_1 = the span of the member, in metres, and Z is the required section modulus of the steel stiffening member obtained from Section 2.

3.3 Bimetallic joints

3.3.1 Where aluminium erections are arranged above a steel hull, details or the arrangements in way of the bimetallic connections are to be submitted.

■ *Section 4* Bulwarks and other means for the protection of crew and passengers

4.1 General requirements

4.1.1 All ships having accommodation are to be fitted with a bulwark from the stem to the forward end of the foremost hatchway, forward cargo tank on tankers, and from the stern to the forward end of the aft deckhouse. The height of forward bulwarks is to be not less than 500 mm and that for aft bulwarks not less than 450 mm. In way of deckhouse doors the bulwark height is to be locally increased to 900 mm, this may be effected by fitting a rail on top of the bulwark.

4.1.2 Plate bulwarks may be replaced by guard rails or by a combination of a bulwark with guard rails on top, except forward where a plate bulwark is required.

4.1.3 Where bulwarks are fitted in the midship region, adequate freeing arrangements are to be provided.

4.2 Requirements for various ship types

4.2.1 In addition to 4.1.1, all open deckspaces on passenger ships, to which passengers have access, are to be fitted with bulwarks or guard rails, having a minimum height of 900 mm. The opening below the lowest course of rails is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart.

4.2.2 In addition to 4.1.1, tankers are to be provided with guard rails of at least 900 mm high over the full length of the cargo zone. On trunk deck tankers the guard rails are to be fitted on the topside of the trunk. The guard-rails should have at least two courses, the lower one fitted at approximately half height, i.e. about 450 mm above deck.

4.2.3 Other types of ships are to be fitted with bulwarks and/or guard/handrails, suitable for the type of ship and the service requirements. Bulwarks on push barges may be omitted.

4.2.4 Attention is drawn to National or International requirements by which the fitting of additional footrails or handrails may be required.

4.3 Bulwark and guard rail construction

4.3.1 Plate bulwarks are to be efficiently supported by stays attached to the deck. These stays are to be fitted in way of beams or equivalent underdeck stiffening and are not to be spaced more than 2,0 m apart. Guard-rail supports are not to be spaced more than 3,0 m apart.
The bulwark thickness is to be not less than:

$$t = 4 + 0{,}015\,(L - 40) \text{ mm}$$

L is to be taken not less than 40 m.

4.4 Means of escape

4.4.1 In accommodation spaces two means of escape are generally to be provided.

4.4.2 For means of escape from passenger spaces on passenger ships, *see* Pt 4, Ch 9,1.7.

Section 1
General

1.1 Application

1.1.1 Requirements are given:

(a) For decks on which wheeled vehicles are to be used.
(b) For the strengthening of ships intended for navigation in ice.

1.1.2 The requirements of this Chapter are to be taken in conjunction with the Chapters of Parts 3 and 4 applicable to the particular ship type.

Section 2
Decks loaded by wheeled vehicles

2.1 General

2.1.1 Where it is proposed either to stow wheeled vehicles on the deck or to use wheeled vehicles for cargo handling, the deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a deck in this location.

2.2 Loading

2.2.1 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Shipbuilder. These details are to include the wheel load, axle and wheel spacing, tyre print dimensions and type of tyre for the vehicles.

2.2.2 For design purposes where wheeled vehicles are to be used for cargo handling, the deck is to be taken as loaded with a normal head of cargo, except in way of the vehicle.

2.3 Deck plating

2.3.1 The deck plating thickness is to comply with Table 9.2.1(1).

Table 9.2.1 Loading by wheeled vehicles

Item	Parameter	Requirements
(1) Deck plating	Plating thickness	$t = \alpha s + 1{,}5$ mm, *see* Note
(2) Deck beams, longitudinals and stiffeners when fork lift trucks are to be used	Section modulus	$Z = 0{,}375 K_1 P\, l_e + 1{,}25 K_2\, h\, s\, l_e^2$ cm^3
(3) Deck beams, longitudinals and stiffeners for decks permanently used for vehicles, in association with a value of *h* which need not exceed 2,5 m	Section modulus	$Z = 0{,}536 K_1 P\, l_e + 1{,}25 K_2\, h\, s\, l_e^2$ cm^3
(4) Deck girders and transverses	Section modulus	$Z = 4{,}75 b\, h\, l_e^2$ cm^3
Symbols		
b = mean width of plating supported by a deck girder or transverse, in metres h = normal load height on the deck, in metres, *see* Ch 3,4 l_e = effective length, in metres, of the beam between span points, *see also* Ch 3,3.3 s = spacing of stiffeners, in metres t = thickness of plating, in mm K_1 and K_2 are factors given in Table 9.2.4 P = total weight of the vehicle divided by the number of axles. Where the distribution of weight is not uniform, P is to be taken as the maximum axle load. For fork lift trucks, the total weight is to be applied to one axle, in tonnes P_1 = corrected patch load obtained from Table 9.2.2, in tonnes Z = section modulus of the member, in cm^3, *see* Ch 3,3.2 α = thickness coefficient obtained from Fig. 9.2.1 β = tyre print coefficient used in Fig. 9.2.1 = $\log\left(\frac{P_1}{s^2} \times 10\right)$		
NOTE Where the necessary data of fork lift trucks are not initially available, the deck plate thickness may be estimated from the maximum beam spacing to plate thickness ratios *s*/*t* given in Table 9.2.3.		

Table 9.2.2 Corrected patch load calculation

Symbols	Expression
a, s, u and v are as defined in Fig. 9.2.1 P_1 = corrected patch load, in tonnes ϕ_1 = patch aspect ratio correction factor ϕ_2 = panel aspect ratio correction factor ϕ_3 = wide patch load factor P_w = load, in tonnes, on the tyre print. For closely spaced wheels, the shaded area shown in Fig. 9.2.1 may be taken as the combined print	$P_1 = 1{,}25\phi_1\,\phi_2\,\phi_3\,P_w$
	$\phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$ $v_1 = v$, but $> s$ $u_1 = u$, but $> a$
	$\phi_2 = 1{,}0$ for $u \leq (a - s)$ $= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a - u)}$ for $a \geq u > (a - s)$ $= 0{,}77\dfrac{a}{u}$ for $u > a$
	$\phi_3 = 1{,}0$ for $v < s$ $= 0{,}6\dfrac{s}{v} + 0{,}4$ for $1{,}5 > \dfrac{v}{s} > 1{,}0$ $= 1{,}2\dfrac{s}{v}$ for $\dfrac{v}{s} \geq 1{,}5$

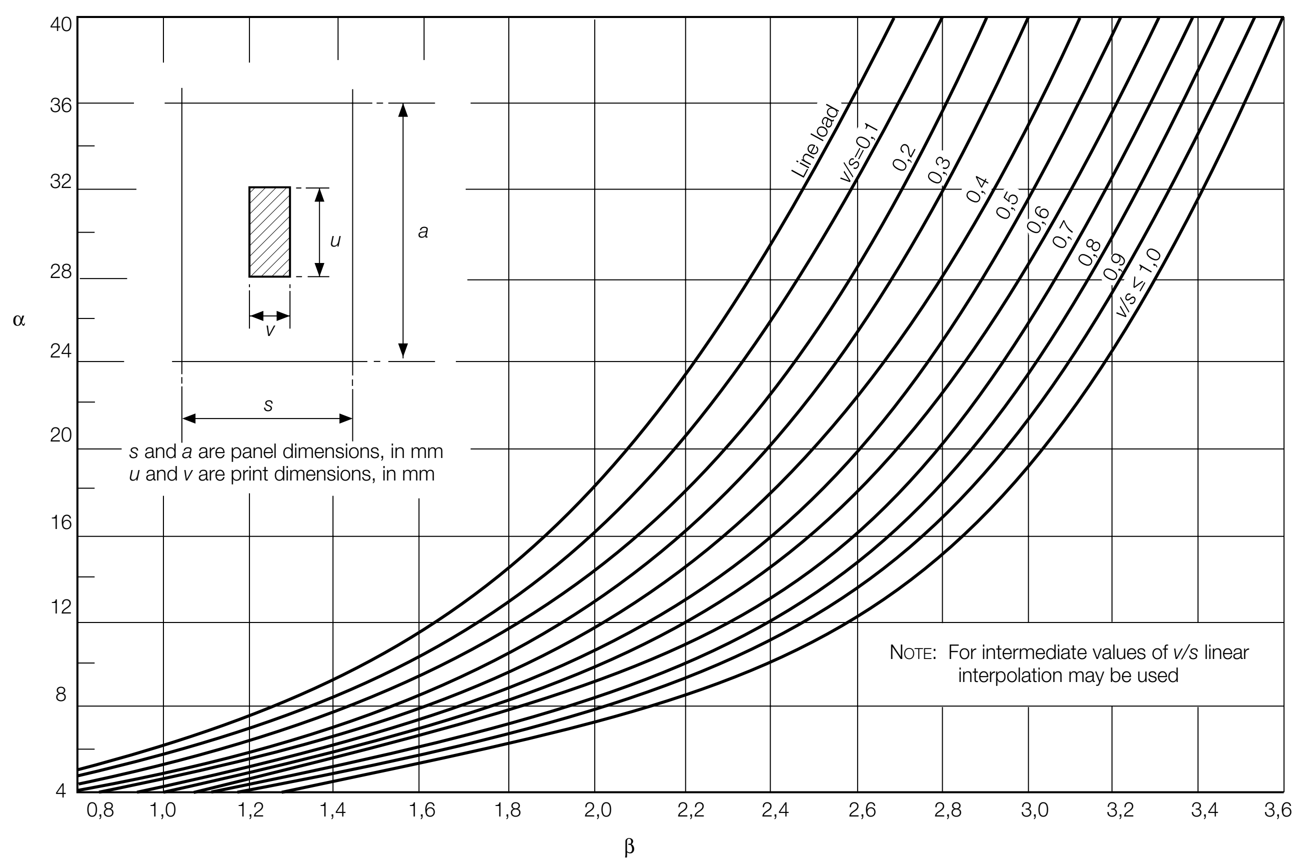


Fig. 9.2.1 Tyre print load stress factor

Table 9.2.3 Approximate deck thickness for fork lift trucks

Capacity of fork lift, in tonnes	$\frac{s}{t}$ (max.)
1,0	0,085
5,0	0,045
10,0	0,037
15,0	0,034
20,0	0,032

Table 9.2.4 Values of K_1 and K_2

$\frac{\text{Wheel spacing*}}{\text{Beam Span}}$	K_1	K_2
0,1	15,4	1,89
0,2	14,6	1,845
0,3	13,35	1,730
0,4	11,8	1,55
0,5 and greater	10,1	1,30
*Outer wheel to outer wheel on axles with multiple wheel arrangements		

2.3.2 Where it is proposed to use vehicles having steel wheels, deck thicknesses will be specially considered.

2.3.3 Where transversely framed decks contribute to the hull girder strength or where secondary stiffening is fitted perpendicular to the direction of vehicle lanes, the thickness, *t*, derived from Table 9.2.1 is to be increased by 1,0 mm.

2.3.4 Where decks are designed for the exclusive carriage of unladen wheeled vehicles, the deck plate thickness, *t*, derived from Table 9.2.1 may be reduced by 0,75 mm.

2.3.5 Where it is proposed to carry tracked vehicles, the patch dimensions may be taken as the track print dimensions and P_w is to be taken as half the total weight of the vehicle. The deckplate thickness, *t*, derived from Table 9.2.1 is to be increased by 0,5 mm. Deck fittings in way of vehicle lanes are to be recessed.

2.3.6 If wheeled vehicles are to be used on insulated decks or tanktops, consideration will be given to the permissible loading in association with the insulation arrangements and the plating thickness.

2.4 Deck beams and longitudinals

2.4.1 The section modulus, *Z*, of deck beams or longitudinals is to be not less than that required for a deck in this location, nor less than the following:

(a) For general purpose cargo decks where fork lift trucks are to be used, the value of *Z* is to be as in Table 9.2.1(2).

(b) For permanent vehicle decks in association with a value of *h* which need not exceed 2,5 m, *Z* is to be as in Table 9.2.1(3).

(c) For decks designed for the carriage of wheeled vehicles only:
that required to satisfy the most severe arrangement of print wheel loads on the stiffener in association with a bending stress of 100 N/mm^2 (10,2 kgf/mm^2) assuming 100 per cent end fixity.

2.5 Deck girders and transverses

2.5.1 Where the load on deck girders and transverses is uniformly distributed, the section modulus is to comply with Table 9.2.1(4).

2.5.2 Where the member supports point loads, with or without the addition of uniformly distributed load, the section modulus is to be based on a stress of 123,6 N/mm^2 (12,6 kgf/mm^2) assuming 100 per cent end fixity.

2.5.3 Where it is proposed to carry tracked vehicles, the total weight of the vehicle is to be taken when determining the section modulus of the transverse at the top of a ramp or at other changes of gradient.

2.6 Heavy and special loads

2.6.1 Where heavy or special loads, such as machinery transporters or large tracked vehicles are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered.

■ *Section 3* Strengthening for navigation in ice

3.1 General

3.1.1 This Section applies to all ships for which the class notation ‘ICE’ is desired. The class notation ‘ICE’ is intended for ships navigating in light ice conditions. The requirements of this Section are to be complied with in addition to the Rule requirements so far as applicable for the particular type of ship.

3.1.2 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2 to which reference should be made on the survey request form.

3.1.3 The requirements of this Section are applicable when transverse side shell framing is adopted. Special consideration will be given to proposals for longitudinal framing.

3.1.4 Ships specially designed for ice breaking duties will be individually considered.

3.2 Definitions

3.2.1 Ice belt is that part of the shell structure in the forward region which has to be reinforced. The longitudinal extent aft of this ice belt is the greater of the following:

(a) From the forward perpendicular to aft for a length equal to the breadth of the ship.

(b) From the forward perpendicular to aft where the ship reaches its greatest breadth plus 10 per cent of that distance.

The vertical extent of this ice belt is from 300 mm below the light waterline to 300 mm above the load waterline. Swim ends forward are part of the ice belt over their full vertical extent.

3.2.2 Light waterline is the lowest waterline, on which the ship is expected to navigate, taking account of trim.

3.2.3 Load waterline is the deepest waterline on which the ship is expected to navigate.

3.3 Shell plating and framing

3.3.1 The thickness of the shell plating in way of the ice belt is to be as required by Table 9.3.1.

3.3.2 Intermediate ice frames are to be fitted over the extent of the ice belt; and their scantlings are to comply with the requirements of Table 9.3.1. The ends of these frames may be sniped.

3.3.3 A side stringer is to be fitted over the longitudinal extent of the ice belt a position about half way between light and load waterlines and efficiently connected to frames and shell. The scantlings of this stringer are to be as required by Table 9.3.1.

3.4 Stem

3.4.1 A bar stem or plate stem is to comply with Table 9.3.1. Bar and plate stems, and their adjoining shell plating, are to be supported by horizontal webs, with a thickness equal to the shell plating in way, connected to the first frame, and spaced not more than 0,5 m apart. Furthermore, a centreline stiffener is required inside a plate stem. This centreline stiffener may be of the same scantlings as the fore peak frames.

Table 9.3.1 Ice strengthening

Item	Parameter	Requirements
(1) Shell plating and swim end plating (in way of ice belt)	Plating thickness	t_i = $1,5t_r$ mm
(2) Intermediate ice frames	Section modulus	Z_i = $0,75Z_r$ cm^3
(3) Side stringer	Section modulus	Z_s = $2Z_r$ cm^3
(4) Bar stem	Area	A = $0,75L$ cm^2
(5) Plate stem	Thickness	The greater of: t_s = $0,10L + 5$ mm t_s = 12 mm
(6) Rudder stock and pintles	Diameter	δ_i = $1,15\delta_r$ mm, *see* Note
(7) Rudder plating and webs	Thickness	t_w = $1,25t_{rs}$ mm
(8) Solepiece	Transverse section modulus	Z_{sp} = $1,15Z_{rs}$ cm^3

Symbols

t_i = thickness of shell plating in way of ice belt, in mm
t_r = Rule thickness of shell plating, or swim end plating, in mm
t_{rs} = Rule thickness of rudder plating or web plating, in mm
t_s = thickness of plate stem in way of ice belt, in mm
t_w = thickness of rudder plating or web plating, increased for navigation in ice, in mm
A = area of bar stem in way of ice belt, in cm^2
L = length of ship, in metres, *see* Ch 1,6.1
Z_i = section modulus of intermediate ice frames, in cm^3
Z_r = section modulus of the Rule main frames, in cm^3
Z_{rs} = Rule transverse section modulus of solepiece, in cm^3
Z_s = section modulus of side stringer in way of ice belt, in cm^3
Z_{sp} = transverse section modulus of solepiece increased for navigation in ice, in cm^3
δ_i = diameter of rudder stock or pintle increased for navigation in ice, in mm
δ_r = Rule diameter of rudder stock or pintle, in mm

NOTE
The gudgeons, rudder couplings and steering gear are to be based on the rudder stock diameter increased for navigation in ice.

3.5 Rudder and sternframe

3.5.1 The rudder stock diameter, pintle diameter and rudder plating and webs are to be as required by Table 9.3.1. The gudgeons, coupling, main piece and steering gear are to be based on the increased diameter of the rudder stock required for navigation in ice.

3.5.2 The solepiece section modulus for transverse bending is to be as required by Table 9.3.1.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter is applicable to all ship types and components.

1.1.2 Requirements are given in this Chapter for the following:

(a) Weld scantlings, weld procedures, workmanship and weld details.

(b) End connection scantlings and constructional details for stiffening members.

(c) Primary member proportions, stiffening and construction details.

1.2 Symbols

1.2.1 Symbols are defined as necessary in each Section.

■ *Section 2* Welding

2.1 General

2.1.1 Details of the welded connections of main structural members, including type and size of welds, are to be clearly indicated on the plans submitted for approval. This includes welded connections to steel castings. The extent to which automatic welding is used should be indicated.

2.1.2 Unless otherwise indicated, all welding is to be in accordance with the requirements of Chapter 13 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2 Fillet welds

2.2.1 The throat thickness of fillet welds is to be determined from:

$$\text{Throat thickness} = t_p \times \text{weld factor} \times \frac{d}{s}$$

where

d = the distance between start positions of successive weld fillet, in mm

s = the length, in mm, of coreectly proportioned weld fillet, clear of end craters, and is to be not less than 75 mm

t_p = plate thickness, on which weld fillet size is based, in mm

see also Fig. 10.2.1.

Weld factors are given in Tables 10.2.1 and 10.2.2

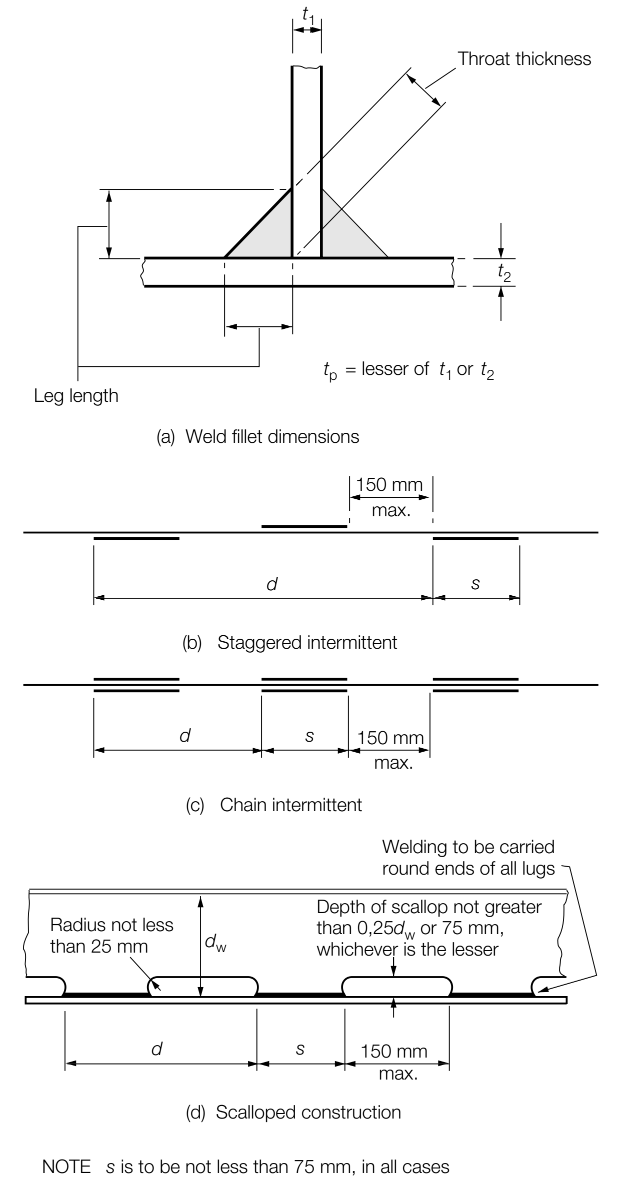


Fig. 10.2.1 Weld types

Table 10.2.1 Weld factors (*see continuation*)

Item	Weld factor	Remarks
(1) General application:		except as required below
Watertight plate boundaries	0,34	
Non-tight plate boundaries	0,13	
Longitudinals, frames, beams, and other secondary members to shell, deck or bulkhead plating	0,10 0,13 0,21	 in tanks in way of end connections
Panel stiffeners, etc.	0,10	
Overlap welds generally	0,27	
(2) Bottom construction in way of holds or tanks:		
Non-tight centre girder: to keel to inner bottom	0,27 0,21	 no scallops
Non-tight boundaries of floors, girders and brackets	0,21 0,27	in way of 0,2 x span at ends in way of brackets at lower end of main frame
Inner bottom longitudinals or reverse frames	0,13	under holds strengthened for heavy cargoes
Connection of floors to inner bottom in way of plane bulkheads or corrugated and double plate bulkheads supported on inner bottom. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material
(3) Hull framing:		
Webs of web frames and stringers: to shell to face plate	 0,16 0,13	
Tank side brackets to shell and inner bottom	0,34	
(4) Decks and supporting structure:		
Strength deck plating to shell		as shown in Table 10.2.5 but alternative proposals will be considered
Other decks to shell and bulkheads (except where forming tank boundaries)	0,21	generally continuous
Webs of cantilevers to deck and to shell in way of root bracket	0,44	
Webs of cantilevers to face plate	0,21	
Pillars: fabricated end connections end connections (tubular)	0,10 0,34 full penetration	 *see* Note 1
Girder web connections and brackets in way of pillar heads and heels	0,21	continuous
(5) Bulkheads and tank construction:		
Plane, double plate and corrugated watertight bulkhead boundary at bottom, bilge, inner bottom and deck	0,44	weld size to be based on thickness of bulkhead plating weld material to be compatible with bulkhead plating material
Boundary at bottom, bilge, inner bottom and deck	0,44	
Secondary members where acting as pillars	0,13	
Non-watertight pillar bulkhead boundaries	0,13	
Perforated flats and wash bulkhead boundaries	0,10	

Table 10.2.1 Weld factors (*continued*)

Item	Weld factor	Remarks
(6) Structure in cargo tanks of tankers:		
Bottom longitudinals to shell	0,21	
Longitudinal of flat-bar type to plating		
Connections between primary structural members	0,44 0,34	at bottom at deck
Oiltight bulkhead boundaries: longitudinal bulkhead transverse bulkhead	 0,44 0,44 0,34	 at bottom at deck, sides and longitudinal bulkhead
Vertical corrugations to an inner bottom	full penetration	*see* Note 2
Non-tight bulkhead boundaries to plating	0,21	
(7) Structure in machinery space:		
Centre girder to keel and inner bottom	0,27	
Floors to centre girder in way of engine, thrust and boiler bearers	0,27	
Floors and girders to shell and inner bottom	0,21	
Main engine foundation girders: to top plate to hull structure	 deep penetration to depend on design	 edge to be prepared with maximum root 0,33t_p deep penetration generally
Floors to main engine foundation girders	0,27	
Brackets, etc., to main engine foundation girders	0,21	
Transverse and longitudinal framing to shell	0,13	
(8) Fore peak construction:	all internal structure	0,13 unless a greater weld factor is required
(9) After peak construction:		
All internal structure and stiffeners on after peak bulkhead	0,21	unless a greater weld factor is required
(10) Superstructure and deckhouses:		
Connection of external bulkheads to deck	0,34 0,21	1st and 2nd tier erections elsewhere
Internal bulkheads	0,13	
(11) Hatchways and closing arrangements:		
Hatchways coamings to deck	0,34	
Hatch cover rest bar	0,16	
Hatch coaming stays to coaming	0,13	
Hatch coaming stays to deck	0,21	
Cleats and fittings	0,44	full penetration welding may be required
Primary and secondary stiffening of hatch covers	0,10	0,13 for tank covers and where covers strengthened for loads over

Table 10.2.1 **Weld factors** (*conclusion*)

Item	Weld factor	Remarks
(12) Steering control systems:		
Rudder:		
Fabricated mainpiece and mainpiece to side plates and webs	0,44	
Slot welds inside plates	0,44	
Remaining construction	0,21	
Fixed and steering nozzles:		
Main structure	0,44	
Elsewhere	0,21	
Fabricated housing and structure of thruster units, stabilizers, etc:		
Main structure	0,44	
Elsewhere	0,21	
(13) Miscellaneous fittings and equipment:		
Rings for manhole type covers, to deck or bulkhead	0,34	
Frames of shell and weathertight bulkhead doors	0,34	
Stiffening of doors	0,21	
Ventilator, air pipe, etc., coamings to deck	0,21	
Ventilator, etc., fittings	0,21	
Scuppers and discharges, to deck	0,44	
Masts, derrick posts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
Deck machinery seats to deck	0,21	generally
Mooring equipment seats	0,21	generally, but increased or full penetration welding may be required
Bulwark stays to deck	0,21	
Bulwark attachment to deck	0,34	
Guard rails, stanchions, etc., to deck	0,34	
Bilge keel ground bars to shell	0,34	Continuous fillet weld, minimum throat thickness 4 mm
Bilge keels to ground bars	0,21	Light continuous fillet weld, minimum throat thickness 3 mm
Fabricated anchors	full penetration	

NOTES
1. Where pillars are fitted inside tanks or under watertight flats, the end connection is to be such that the tensile stress in the weld does not exceed 108 N/mm^2 (11 kgf/mm^2).
2. Up to a thickness of 10 mm double continuous fillet welding may be applied whereby a weld factor of 0,50 is to be used.

2.2.2 Where an approved deep penetration procedure is used, the fillet leg length calculated from the weld factors given in the Tables may be reduced by 15 per cent provided that the Shipyard is able to meet the following requirements:

(a) Use of a welding consumable approved for deep penetration welding in accordance with Chapter 13 of the Rules for Materials for either the 'p' or 'T' techniques.

(b) Demonstrations by way of production weld testing that the minimum required penetration depths (i.e. throat thicknesses) are maintained. This is to be documented on a monthly basis by the Shipyard, and made available to the Surveyor on request.

A reduction of 20 per cent may be given provided that in addition to the requirements of (a) and (b) the Shipyard is able to consistently meet the following additional requirements:

(c) The documentation required in (b) is to be completed and made available to the Surveyor upon request on a weekly basis.

(d) Suitable process selection confirmed by satisfactory welding procedure tests covering both minimum and maximum root gaps.

2.2.3 The leg length of the weld is to be not less than $\sqrt{2}$ x the specified throat thickness.

Table 10.2.2 Throat thickness limits

Item	Throat thickness, in mm Minimum	Throat thickness, in mm Maximum
(1) Double continuous welding	$0{,}21t_p$	$0{,}44t_p$
(2) Intermittent welding	$0{,}27t_p$	$0{,}44t_p$ or 4,5
(3) All welds, overriding minimum:		
(a) Plate thickness $t_p \leq 7{,}5$ mm		
Hand or automatic welding	3,0	—
Automatic deep penetration welding	3,0	—
(b) Plate thickness $t_p > 7{,}5$ mm		
Hand or automatic welding	3,25	—
Automatic deep penetration welding	3,0	—

NOTES
1. In all cases, the limiting value is to be taken as the greatest of the applicable values given above.
2. Where t_p exceeds 25 mm, the limiting values may be calculated using a notional thickness equal to $0{,}4\,(t_p + 25)$ mm.
3. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

2.2.4 The plate thickness, t_p, to be used in the above calculation, is generally, to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet will be considered.

2.2.5 Double continuous welding is to be adopted as required by section 2.2.7 and is recommended in the following locations:
(a) All welding inside tanks.
(b) All welding in chain lockers and other wet spaces.
(c) All welding exposed to the weather.

2.2.6 Except as perscribed by Table 10.2.1, for corrugated bulkheads, the throat thickness of the weld is not to be outside the limits specified in Table 10.2.2.

2.2.7 Continuous welding is to be adopted in the following locations, and may be used elsewhere if desired:
(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.
(b) Boundaries of tanks and watertight compartments.
(c) All structure in the after peak and the after peak bulkhead stiffeners.
(d) All welding inside tanks intended for chemicals or edible liquid cargoes.
(e) All lap welds in tanks.
(f) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections.
(g) Other connections or attachments, where considered necessary, and in particular the attachment of minor fittings to higher tensile steel plating.
(h) Fillet welds where higher tensile steel is used.

2.2.8 Where intermittent welding is used, the welding is to be made continuous in way of brackets, lugs and scallops and at the orthogonal connections with other members.

2.2.9 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively, a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

2.3 Full penetration welding

2.3.1 Full penetration welding is to be adopted for all boundaries of the hull envelope plating below the sheerstrake (including shell penetrations) to the sea and as indicated in Table 10.2.1.

2.4 Welding of primary and secondary member end connections

2.4.1 Weld factors for the connections of primary structure are given in Table 10.2.3.

2.4.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0{,}85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

2.4.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

2.4.4 The throat thickness limits given in Table 10.2.2 are to be complied with.

2.4.5 The welding of secondary member end connections is to be not less than as required by Table 10.2.4.

2.4.6 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the welding area is to be at least 25 per cent greater than the cross-sectional area of the member.

2.5 Welding consumables and equipment

2.5.1 Welding consumables used and associated equipment is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

Table 10.2.3 Connections of primary structure

Primary member face area, in cm^2		Position[(1)]	Weld factor			
			In tanks		In dry spaces	
Exceeding	Not exceeding		To face plate	To plating	To face plate	To plating
	30,0	At ends Remainder	0,21 0,10	0,27 0,16	0,21 0,10	0,21 0,13
30,0	65,0	At ends Remainder	0,21 0,13	0,34 0,27	0,21 0,13	0,21 0,16
65,0	95,0	At ends Remainder	0,34 0,27[(2)]	0,44[(3)] 0,34	0,21 0,16	0,27 0,21

NOTES
1. The weld factors 'at ends' are to be applied for 0,2 x the overall length of the member from each end, but at least beyond the toes of the member end brackets. On vertical webs the increased welding may be omitted at the top, but is to extend at least 0,3 x overall length from the bottom.
2. Weld factor 0,34 in cargo oil tanks.
3. Where the web plate thickness is increased locally, the weld size may be based on the thickness clear of the increase, but is to be not less than 0,34 x the increased thickness.
4. The final throat thickness of the weld fillet to be not less than $0{,}34t_p$ in cargo tanks of tankers.

Table 10.2.4 Secondary member end connection welds

Connection	Weld area, A_w, in cm^2	Weld factor
(1) Stiffener welded direct to plating	$0{,}25A_s$ or 6,5 cm^2 whichever is the greater	0,34
(2) Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	1,2 Z	0,27
(b) in tank	1,4 Z	0,34
(c) main frame to tank side bracket in 0,15L forward	as (a) or (b)	0,34
(3) Bracket welded to face of stiffener and bracket connection to plating	—	0,34
(4) Stiffener to plating for 0,1 x span at ends, or in way of end bracket if that be greater	—	0,34

Symbols

A_s = cross sectional area of the stiffener, in cm^2
A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm
Z = the section modulus, in cm^2, of the stiffener on which the scantlings of the bracket are based, *see* Section 3

NOTE
For maximum and minimum weld fillet sizes, *see* Table 10.2.2.

2.6 Welding procedures and welder qualifications

2.6.1 Welding procedures are to be established for the welding of all joints in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

2.6.2 All welding procedures are to be tested and qualified in accordance with the requirements of Chapter 12 of the Rules for Materials and are to be approved by the Surveyor prior to construction.

2.6.3 Welders and welding operators are to be proficient in the type of work to be undertaken and are to be qualified in accordance with the requirements specified in Chapter 12 of the Rules for Materials.

2.7 Inspection of welds

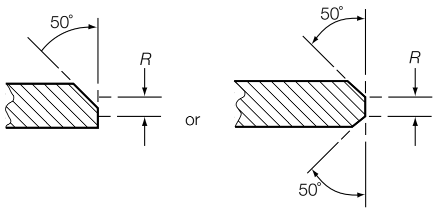
2.7.1 Effective arrangements are to be provided by the Builder for the inspection of finished welds to ensure that all welding has been satisfactorily completed.

2.7.2 All finished welds are to be subjected to non-destructive examination in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

Table 10.2.5 Weld connection of strength deck plating to sheerstrake

Item	Stringer plate thickness, mm	Weld type
1	$t \leq 15$	Double continuous fillet weld with a weld factor of 0,44
2	$15 < t \leq 20$	Single vee preparation to provide included angle of 50° with root $R \leq \frac{1}{3}t$ in conjunction with a continuous fillet weld having a weld factor of 0,39 or Double vee preparation to provide included angles of 50° with root $R \leq \frac{1}{3}t$
3	$t > 20$	Double vee preparation to provide included angles of 50° with root $R \leq \frac{1}{3}t$ but not to exceed 10 mm

Where t = thickness of stringer plate, in mm



Single vee preparation Double vee preparation

NOTES
1 Welding procedure, including joint preparation, is to be specified. Procedure is to be qualified and approved for individual Builders.
2. *See also* 2.2.9.
3. For thickness t in excess of 20 mm the stringer plate may be bevelled to achieve a reduced thickness at the weld connection. The length of the bevel is in general to be based on a taper not exceeding 1 in 3 and the reduced thickness is in general to be not less than 0,65 times the thickness of stringer plate or 20 mm, whichever is the greater.
4. Alternative connections will be considered.

■ *Section 3* Secondary member end connections

3.1 General

3.1.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends in accordance with the requirements of this Section.

3.1.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member. For determination of span point, *see* Ch 3,3.3.

3.2 Symbols

3.2.1 The symbols used in this Section are defined as follows:

Z = the section modulus of the stiffening member, in cm^3

a, b = the actual lengths, in mm, of the two arms of the bracket, measured from the plating to the toe of the bracket, *see* Fig. 10.3.1.

3.3 Basis for calculation of bracket connections

3.3.1 Scantlings of bracket connections are based on the following criteria:

(a) Where a bracket is connecting a stiffener to a primary member, the bracket is to be based on the modulus of the stiffener.

(b) Where a main transverse frame terminates, the bracket at the head of the frame is to be based on the modulus of the frame.

(c) Where, in the midship region, a longitudinal strength member is cut at a transverse supporting member and the continuity of strength is provided by brackets, the bracket is to be based on the cross-sectional area and the modulus of the longitudinal member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

(d) Elsewhere, the lesser modulus of the members being connected by the bracket.

3.4 Scantlings of end brackets

3.4.1 The lengths, a and b, of the arms are to be measured in accordance with Fig. 10.3.1 and are to be such that:

(a) $a + b \geq 2{,}0l$

(b) $a \geq 0{,}8l$

(c) $b \geq 0{,}8l$

where

l is the length of a bracket as required by Table 10.3.1.

3.4.2 Bracket scantlings are to comply with the requirements of Table 10.3.1.

3.4.3 Where the bracket is lapped on to the stiffening member, the length and width of overlap is to be adequate to provide for the required area of welding, but the length of overlap should be not less than the depth of the stiffener.

3.4.4 For the purpose of these Rules, bracket connections not complying with these minimum requirements are considered as bracketless connections.

3.5 Arrangement and details

3.5.1 The modulus of the bracket through the throat is to be not less than that of the smaller stiffening member to be connected.

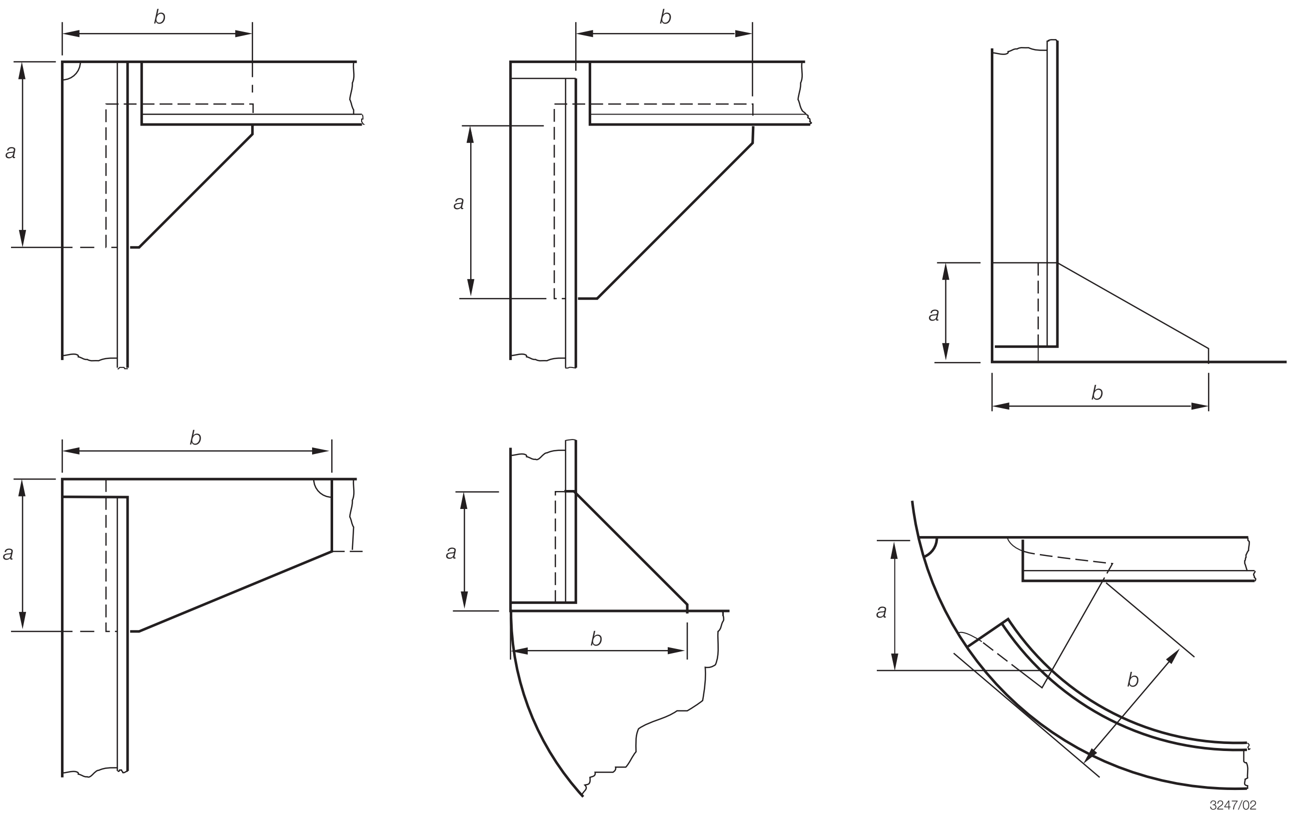


Fig. 10.3.1 Diagrammatic arrangements of stiffener end brackets

Table 10.3.1 Bracket scantlings

Parameter	Requirement
Length of a bracket	The greater of the following: $l = 9\sqrt{Z} + 80 + d_s$ mm, or $l = 2d_s$ mm
Thickness of a bracket (a) unflanged	$t = 5 + 0{,}3\sqrt{Z}$ mm, *see* Note
(b) flanged	The greater of the following: $t = 4 + 0{,}3\sqrt{Z}$ mm, or $t = 5$ mm
Flange width	$t = 50\left(1 + \frac{Z}{1000}\right)$ mm
Symbols	
b_f = breadth of the flange, in mm d_s = depth of the stiffening member, in mm l = arm length of bracket, in mm Z = as defined in 3.2.1	
NOTE Where the length of the free edge of a bracket exceeds 50*t* mm, edge stiffening is to be fitted or the thickness is to be suitably increased.	

3.5.2 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

3.5.3 The toes of brackets should not land on unstiffened panels of plating. Special care should be taken to avoid notch effects at the toes of brackets.

3.6 Bracketless connections

3.6.1 For the purpose of these Rules, bracketless connections are divided into two types as follows:

Type 1: Connections of stiffening members to each other, with a bracket connection as per Fig. 10.3.1 or without a bracket, *see* Fig. 10.3.2.

Type 2: Stiffening members which are not connected at their ends, *see* Fig. 10.3.2.

3.6.2 Type 2 connections may only be adopted at watertight and hold-bulkhead stiffeners, wash bulkhead stiffeners and at stiffeners on centreline division bulkheads in tanks.

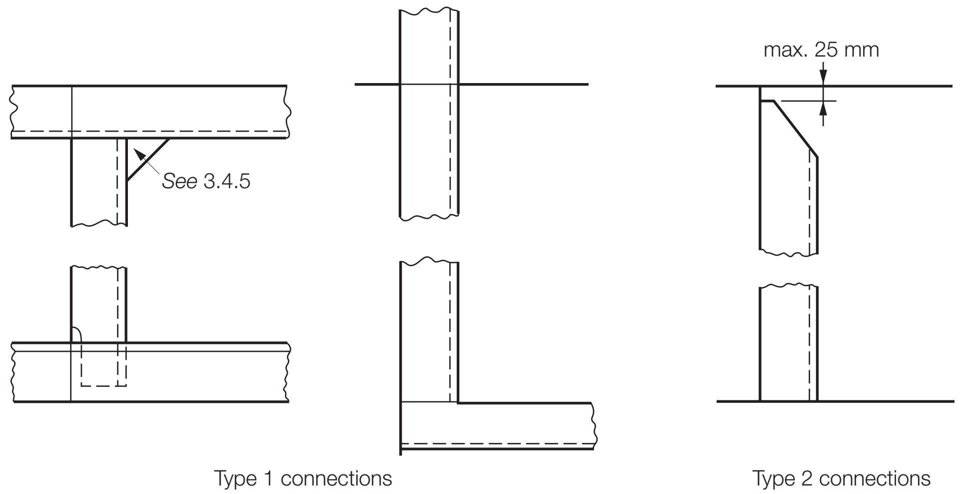


Fig. 10.3.2 Types of bracketless end connections

3.7 Correction of stiffening member modulus in relation to end connections

3.7.1 Where a stiffening member is fitted with end brackets complying with, or in excess of the requirements of 3.4, the modulus of the member need not be corrected.

3.7.2 The modulus of bracketless stiffeners is to be increased as follows:

Type 1 connection: increase 10 per cent per end connection.
Type 2 connection: increase 25 per cent per end connection.

3.8 End connections of corrugated bulkheads

3.8.1 The constraint of the end connection is to be assured by the positioning of floors and/or carlings or a corrugated bulkhead in line with the corrugated bulkhead under consideration. This type of connection is considered as a bracketless Type 1 connection, *see also* Fig. 10.3.3. Where the bulkhead corrugations are not supported, the connection is considered as a Type 2 connection, *see also* Fig. 10.3.3.

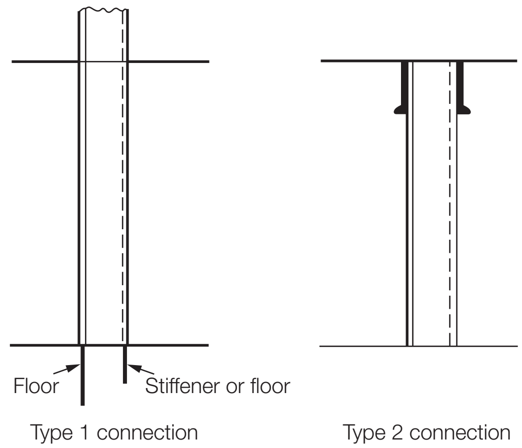


Fig. 10.3.3
End connections of corrugated bulkheads

■ *Section 4* Construction details for primary members

4.1 General

4.1.1 This Section includes the requirements for proportions, stiffening, end connections and construction details for primary members.

4.1.2 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

d_w = depth of member web, in mm
t_w = thickness of member web, in mm
A_f = area of member face plate or flange, in cm^2
S_w = depth of member web, or spacing of stiffeners on member web, whichever is the lesser, in mm.

4.3 Arrangements

4.3.1 Primary members are to be so arranged as to ensure effective continuity of strength and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead or on other members, arrangements are to be made to ensure that they are in alignment. Primary transverse members in a longitudinal framing system are to form a continuous line of support and wherever possible, a complete ring system.

4.3.2 Where a primary member ends at a structure which provides only a low degree of restraint against rotation, the member is generally to extend for at least two frame spaces, or equivalent, beyond the point of support.

4.3.3 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

4.4 Geometric properties and proportions

4.4.1 The geometric properties of the member are to be calculated in association with an effective width of attached plating determined in accordance with Ch 3,3.2.

4.4.2 The minimum thickness or area of material in each component part of the primary member is given in Table 10.4.1.

Table 10.4.1 Minimum thickness of primary structures

Item	Requirement
Member web plate, *see also* 4.5.4	t_w = $0{,}012S_w$ mm but not less than 5 mm
Member face plate, *see* Note	A_f not to exceed $\dfrac{d_w\, t_w}{150}$ cm^2
Plating forming a flange of primary members	Plate thickness not less than $\sqrt{A_f}$ mm, for a width of plate not less than 750 mm
Symbols are as defined in 4.2.1	
NOTE The member face plate area, A_f, may exceed this requirement, provided the lateral stability of the member is improved and the shear stress in the web plate does not exceed 83,4 N/mm^2 (8,5 kg/mm^2).	

4.5 Web stability

4.5.1 Primary members of asymmetrical section are to be supported by tripping brackets, at alternate secondary members. If the section is symmetrical, the tripping brackets may be four stiffener spaces apart.

4.5.2 Tripping brackets are also to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars.

4.5.3 Intermediate secondary members may be welded directly to the web or connected by lugs.

4.5.4 Apart from the requirements of Table 10.4.1, the web thickness of a longitudinal girder at the strength deck within 0,5L amidships is to be not less than $0{,}018S_w$ mm.

4.6 Openings in the web

4.6.1 Where openings are cut in the web, the depth of opening is not to exceed 25 per cent of the web depth, and the opening is to be so located that the edges are not less than 40 per cent of the web depth from the face plate. The length of opening is not to exceed 60 per cent of the secondary member spacing. Where larger openings are proposed, the arrangement and compensation required will be considered. Openings are to have smooth edges and well rounded corners.

4.6.2 Cut-outs for the passage of secondary members are to have smooth edges and rounded corners and are to be kept as small as practicable. The connection of the web plating to the secondary member is to be sufficient for the load to be transmitted to the primary member.

4.7 End connections

4.7.1 End connections of primary members are generally to comply with the requirements of Section 3, taking Z as the section modulus of the primary member.

4.7.2 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

4.7.3 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted.

4.7.4 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate resistance to rotation and displacement of the joint.

■ *Section 5* Structural details

5.1 Continuity and alignment

5.1.1 Special attention is to be paid to structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

5.1.2 Where practicable, pillars and bulkheads should be placed in the same vertical line. Beam slots in girders, etc., in way of pillars, are to be collared.

5.2 Openings

5.2.1 Hatchways and other openings in strength and tween decks are to have rounded corners.

5.2.2 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear stress. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams within one-third of their length from either end, nor in floors or double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating are calculated and found acceptable.

5.2.3 Openings may require to be suitably framed and stiffened.

5.2.4 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges.

5.3 Fittings and attachments

5.3.1 Welding of fair lead stools, mouldings and other fittings to the top edge of the sheer strake within 0,5L amidships, is to be avoided where possible. Bulwarks in this region should also be kept clear of the top edge of the sheer strake, however where welding on the top edge of the sheerstrake cannot be avoided, care is to be taken to minimize any notch effects.

5.3.2 Where a rounded gunwale is adopted, arrangements are to be made to ensure a smooth transition from rounded gunwale to angled gunwale.

5.3.3 Bilge keels, where fitted, are to be attached to a continuous ground bar, welded to the shell. The butts of bilge keels and ground bar should be completed before the bilge keels are welded to the shell. The ends of bilge keels are to be well sniped and arranged to land in way of an internal stiffener.

5.3.4 The quality of welding and general workmanship of fittings and attachments are to be equivalent to that of the main hull structure.

Closing Arrangements to Openings in Shell and Deck, Ventilators, Air Pipes, Sounding Pipes and Discharges

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all ship types detailed in Part 4. In addition to this Chapter, additional requirements for dry cargo ships carrying dangerous goods are given in Pt 4, Ch 1. Additional requirements for tankers carring dangerous liquids in bulk are given in Pt 4, Ch 4.

1.1.2 Requirements are given for:
(a) Steel, aluminium or wooden hatch covers, self-supporting and portable, securing arrangements, tarpaulins and closing arrangements for miscellaneous openings.
(b) Hatchways less than 3 m in length and breadth (requirements for larger hatchways are given in the relevant ship type Chapter, *see* Part 4), cargo tank hatches, ventilators, airpipes, sounding pipes and discharges.

Hatch covers of other materials will be specially considered.

1.1.3 Hatch covers are to be fitted on holds intended for the carriage of perishable cargoes. Means are to be provided for making hatch covers weathertight by fitting tarpaulins or by sealing arrangements to the hatch cover and/or hatch coaming.

1.1.4 The requirements for scantlings and arrangements of the following types of hatch covers are defined in this Chapter:
(a) Self-supporting steel or aluminium, single plate hatch covers stiffened by webs, stiffeners or corrugations.
(b) Self-supporting steel or aluminium, double plate hatch covers having interior webs and stiffeners.
(c) Portable wood, steel or aluminium hatch covers used in conjunction with portable beams, fore and afters and crossbeams if necessary.
(d) Hatch covers on small openings to dry spaces.
(e) Hatch covers and coamings for cargo tanks and similar spaces.

1.1.5 The scantlings specified in the following Sections apply basically to uniformly loaded rectangular hatch covers, being simply supported and with stiffening members arranged primarily in one direction. When covers are stiffened otherwise or concentrated loads are applied, the scantlings are to be determined by direct calculations based on the permissible stresses and deflections given in Table 11.2.2 and are to be submitted for approval.

1.2 Symbols

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

h_H = hatch cover design head, *see* Ch 3,4
l_o = unsupported span of stiffening member, in metres
s = spacing of stiffeners, in metres
d_w = depth of stiffener, in mm
w = width of effective plating included in the section modulus, in metres
t = thickness of plating, in mm
Z = section modulus of stiffening member, in cm^3, *see* Ch 3,3.2
I = moment of inertia of stiffening member, in cm^4, *see* Ch 3,3.2.

■ *Section 2* Self-supporting steel hatch covers

2.1 Plating

2.1.1 The thickness of the plating of steel hatch covers is to be not less than required by Table 11.2.1.

2.2 Webs and stiffeners

2.2.1 The scantlings of steel cover webs and stiffeners are to be not less than required by Table 11.2.1.

Table 11.2.1 Steel hatch cover scantlings

Item	Parameter	Requirements
Top plating for $h_H \leq 0{,}75$ m	Thickness	The greater of: $t = 6s$ mm $t = 2$ mm, *see* Note
Top plating for $h_H > 0{,}75$ m	Thickness	The greater of: $t = 6{,}6s\sqrt[3]{h_H}$ mm $t = 2$ mm, *see* Note
Bottom plating for double plate covers	Thickness	The greater of: $t = 5s$ mm $t = 2$ mm, *see* Note
Webs and stiffeners	Section modulus Inertia Minimum thickness	$Z = 7{,}5 \times s \times h_H \times l_o^2$ cm^3 $I = 2{,}1 \times Z \times l_o$ cm^4 The greater of: $t = 0{,}018d_w$ mm $t = 4$ mm
Effective plating to be included in the section modulus	Width	The lesser of: $w = 0{,}08t$ m $w = s$ m
The symbols are defined in 1.2.1		
NOTE The top plating thickness may be reduced, when the plating is stiffened by swedges or equivalent, provided the maximum permissible stresses and deflections of Table 11.2.2 are not exceeded. Proposals are to be submitted for approval.		

Table 11.2.2 Parameters for direct calculation

Item	Bending stress, in N/mm^2 (kgf/mm^2)	Shear stress, in N/mm^2 (kgf/mm^2)	Deflection, in metres
Steel covers	117,7 (12,0)	168,7 (7,0)	$0{,}004l_o$
Aluminium covers	69,6 (7,1)	40,2 (4,1)	$0{,}004l_o$

■ *Section 3* Self-supporting aluminium hatch covers

3.1 General

3.1.1 This Section applies to hatch covers fabricated from aluminium alloys as defined in Chapter 8 of Lloyd's Register's (hereinafter referred to as 'LR') *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 When aluminium alloys other than those defined in Chapter 8 of LR's Rules for Materials are used, details of this composition and minimum mechanical properties of the material of the finished cover are to be submitted for approval. The approval will be based on the properties of the material, durability, etc.

3.2 Plating

3.2.1 The thickness of the plating of aluminium hatch covers is to be not less than required by Table 11.3.1.

3.3 Stiffeners

3.3.1 The scantlings of stiffeners and swedges of aluminium hatch covers are to comply with the requirements of Table 11.3.1.

Table 11.3.1 Aluminium hatch cover scantlings

Item	Parameter	Requirements
Top and bottom plating, for $h_H \leq 0{,}75$ m	Thickness	The greater of: $t = 8{,}4s$ mm $t = 2$ mm, *see* Note
Top plating for $h_H > 0{,}75$ m	Thickness	The greater of: $t = 9{,}25s \sqrt[3]{h_H}$ mm $t = 2$ mm, *see* Note
Webs and stiffeners	Section modulus Inertia Minimum thickness	$Z = 12{,}75 \times b \times h_H \times l_o^2$ cm^3 $I = 3{,}7 \times Z \times l_o$ cm^4 The greater of: $t = 0{,}025d_w$ mm $t = 4$ mm
Effective plating to be included in the section modulus	Width	The lesser of: $w = 0{,}08t$ m $w = s$ m
The symbols are defined in 1.2.1		
NOTE The top plating thickness may be reduced, when the plating is stiffened by swedges or equivalent, provided the maximum permissible stresses and deflections of Table 11.2.2 are not exceeded. Proposals are to be submitted for approval.		

Section 4
Portable wood, steel or aluminium covers with portable beams

4.1 Wood, steel or aluminium covers

4.1.1 When wood covers are fitted, they are to have a finished thickness of not less than 25 mm, and are to be supported at their edges by beams spaced not more than 600 mm apart. The planks of the wood covers are to be connected at their underside by cross planks having the same thickness as the cover, a width of about 125 mm and spaced at a maximum distance of 1,5 m, *see* Fig. 11.4.2.

4.1.2 The plating of steel covers is to comply with Table 11.2.1, and the plating of aluminium covers is to comply with Table 11.3.1.

4.1.3 The edges of the plating of steel or aluminium are to be adequately stiffened at their sides as necessary for the rigidity of the cover.

4.2 Portable beams, fore and afters and cross beams

4.2.1 Portable wood, steel or aluminium covers are to be supported by a system of beams and fore and afters with cross beams, where necessary, which are to have scantlings as required by Table 11.4.1. For the layout of such arrangements, *see* Fig. 11.4.1.

Table 11.4.1 Scantlings of supporting structure for hatch covers with portable beams

Item	Parameter	Requirements
Portable beams	Section modulus	$Z = 7{,}5 \times b_p \times h_H \times b^2$ cm^3 *see* Note
Fore and after	Section modulus	$Z = 8{,}5 \times b \times h_H \times l_a^2$ cm^3
Cross beam	Section modulus	$Z = 34 \times l_a \times h_H \times b$ cm^3
Additional fore and after (if fitted)	Section modulus	$Z = 4 \times b \times h_H \times l_a^2$ cm^3
Symbols		
Z and h_H are as defined in 1.2.1 b_p, b and l_a = distances, in metres, as shown in Fig. 11.4.1		
NOTE The section modulus of wood portable beams is to be fourteen times the section modulus of steel portable beams.		

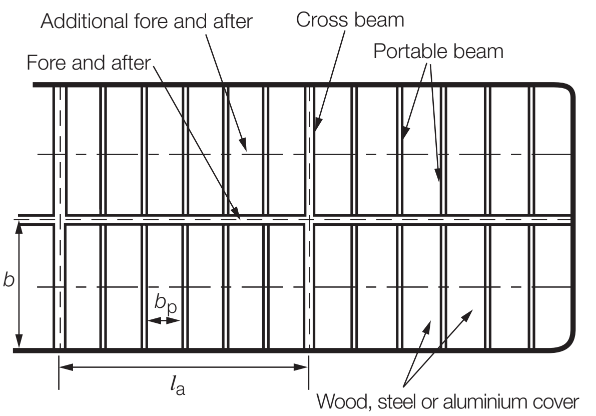


Fig. 11.4.1 Hatch cover layout with portable beams

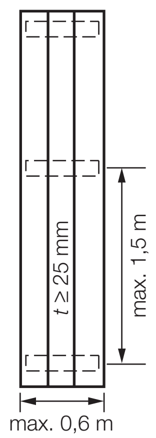


Fig. 11.4.2 Portable wood cover

4.3 Quality of timber

4.3.1 The timber of covers and portable beams is to be of good quality and well preserved.

■ *Section 5* Hatchways for cargo tanks

5.1 General

5.1.1 Hatchways for cargo tanks are to be made of steel. Their construction is to be such that no leakage of liquid or gas occurs. This is also applicable when the tank is subjected to internal pressure.

5.1.2 Hatch coamings on cargo tanks (may act as expansion trunk) are to be at least 500 mm in height. The thickness of the coaming is to be at least 6 mm.

5.1.3 The plating thickness and the stiffening of flat hatch covers are to comply with the requirements of Table 11.5.1.

Table 11.5.1 Steel hatch covers for cargo tanks

Item	Parameter	Requirements
Plating	Thickness	The greater of: $t = 9s + \sqrt{h_4}$ mm $t = 5$ mm
Stiffeners	Section modulus Inertia Minimum depth	$Z = 7{,}5 \times s \times l_e^2 \times h_4$ cm^3 $I = 2{,}1 \times Z \times l_e$ cm^4 $d_w = 50$ mm
Symbols		
t, Z, I and s are as defined in 1.2.1 h_4 = design pressure to be derived from the appropriate ship type Chapter, but to be taken not less than 1 m above the tank deck or 0,5 m above the top of the hatch cover whichever is the greater, in metres l_e = unsupported span of the stiffener, in metres, and is to be taken not less than 1 m		

5.1.4 Panel stiffeners are not normally required on hatch covers smaller than 500 x 500 mm, but efficient edge stiffening is to be fitted.

■ *Section 6* Hatch cover securing arrangements and tarpaulins

6.1 Securing arrangements

6.1.1 Hatch covers are to be provided with securing arrangements to prevent undue movement of the covers, and to ensure suitable compression of the gasket if fitted. When toggles are fitted to ensure compression of the gasket, their number and spacing will be considered in relation to the rigidity of the hatch cover.

6.1.2 Toggles to cargo tank hatch covers are generally to be spaced not more than 450 mm apart, but the number and size are to be commensurate with the loads imposed upon them. When the cover is provided with suitable additional stiffening, the number of toggles may be reduced.

6.1.3 Hinges are not to be used for sealing arrangements unless they are adjustable in height.

6.1.4 On non adjustable hinges the holes for the bolts are to be slotted in order to provide adequate vertical clearance in way to ensure equal packing pressure over the entire hatch by the toggles.

6.2 Tarpaulins

6.2.1 Where tarpaulins are fitted to make hatch covers weathertight, they are to be of ample strength and waterproof. Tarpaulins are to be secured by battens and wedges or equivalent arrangements.

■ *Section 7* Small hatchways

7.1 General

7.1.1 This Section applies to small hatchways to dry spaces with a length and width less than 3 m.

7.2 Construction of coamings

7.2.1 The thickness of the hatch coaming is to be not less than the Rule thickness of the deck around the hatch. When the height of the coaming exceeds 300 mm the upper edge of the coaming is to be stiffened and the coaming may need to be supported by brackets or stays to the deck. Where the height of the coaming plate exceeds the spacing of the deck beams, the thickness of the coaming plate is to be increased or additionally stiffened.

7.3 Hatch covers

7.3.1 Hatch covers on hatches for access to dry spaces may be constructed of steel, aluminium or wood. The scantlings of these covers are to comply with the requirements of Sections 2, 3 or 4, whichever is applicable. The edges of the covers are to be adequately stiffened.

7.3.2 Hatch covers are to be weathertight. The securing arrangements are to be adequate to ensure the weathertightness. Escape hatches are to be capable of being opened from either side.

■ *Section 8* Miscellaneous openings

8.1 Companionways, doors and access openings on weatherdecks

8.1.1 Companionways on exposed decks are to be equivalent in strength and weathertightness to a deckhouse in the same position. The height of the doorway sill above deck is to be not less than 100 mm, but at least 300 mm above the load waterline. When the companionway is leading to the engine room, the height of the doorway sill above deck is to be not less than 400 mm.

8.1.2 For requirements for ships carrying dangerous liquids, *see* Pt 4, Ch 4.

8.2 Manholes

8.2.1 Manholes fitted in decks exposed to the weather are to be closed by strong watertight covers.

8.3 Windows, side scuttles and skylights

8.3.1 Windows and side scuttles fitted in the exposed sides of superstructures and deckhouses, or in the shell above the load waterline, are to have frames of a substantial construction, comparable with the surrounding structure. The glass thickness is to comply with the requirements of Table 11.8.1. Only non-opening windows or side scuttles are permitted in the shell, and the lower edge of the glass is to be at least 500 mm above the load waterline in any condition of list or trim. Windows or side scuttles in the shell are to be adequately protected against direct contact by efficient fenders or are to be recessed into the shell.

Table 11.8.1 Glass thickness for windows and side scuttles

Size of glass, in mm	Thickness, in mm — For windows and side scuttles in the following positions	
	Position A	Position B
300 x 425	6	6
355 x 500	6	6
400 x 560	6	6
450 x 630	6	6
500 x 710	8	6
560 x 800	8	6
900 x 630	10	6
1000 x 710	10	8
1100 x 800	12	8
Side scuttles	8	6

NOTES
1. Position A – The lower edge of the window is less than 2,5 m above the load waterline.
   Position B – The lower edge of the window is 2,5 m or more above the load waterline.
2. The glass is to be toughened safety glass and the quality is to comply with ISO Standard 614 or equivalent standard.

8.3.2 Blinds and deadlights of steel or equivalent material need only be provided for windows or side-scuttles in the shell and places where mechanical damage can occur. The number of blinds and deadlights to be provided is 20 per cent of the total number of openings but at least one cover for every size of opening.

8.3.3 Skylights, where fitted, are to be of substantial construction and securely attached to their coamings. The scantlings of the coamings are to be as required by Section 7. The construction of the glass in skylights is to be as for windows in the same position.

Section 9 Ventilators

9.1 General

9.1.1 The lower edge of ventilator openings on the open deck is to have a height of at least 500 mm above the load waterline, but not less than 100 mm above the deck, and are to be protected against ingress of water. When, due to service conditions, the height of the ventilator coaming is less than 500 mm above the load waterline, the hoods are to be provided with weathertight closing arrangements.

9.1.2 Special requirements for ventilation arrangements in certain types of ships are given in the relevant ship type Chapter in Part 4.

9.2 Construction

9.2.1 The scantlings of exposed ventilator trunks and coamings are to be equivalent to scantlings of deckhouses in the same position. Ventilator trunks leading through cargo spaces or other areas where mechanical damage is likely to occur, are to be protected or additionally stiffened.

Section 10 Air and sounding pipes

10.1 General

10.1.1 Air and sounding pipes are to comply with the requirements of Pt 5, Ch 11,10. Name plates are to be affixed near their upper ends.

10.1.2 Striking plates of suitable thickness or their equivalent means, are to be fitted under all sounding pipes.

10.1.3 Air and sounding pipes leading through cargo containment areas or other spaces where mechanical damage is likely to occur, are to be well protected.

10.2 Height of air pipes

10.2.1 The height of air pipes from the upper surface of exposed decks to a point where water may have access below is normally to be not less than 300 mm, but the height above the load waterline in any loading condition is to be not less than 500 mm.

10.2.2 A lower height may be approved in cases where this is essential for the working of the ship, provided efficient means are fitted against ingress of water into the tank under all service conditions.

10.2.3 For air pipes on ships carrying dangerous goods, *see* Pt 4, Ch 1 and Pt 4, Ch 4 respectively.

10.3 Closing appliances

10.3.1 Openings of air pipes of standard height as in 10.2.1 are to be provided with spray tight arrangements, such as a bend in the upper part of the pipe or equivalent.

10.3.2 Sounding pipes are to be provided with permanently attached efficient means of closing to prevent the free entry of water.

10.3.3 Where the closing appliances on air pipes are not of an automatic type, provision is to be made for pressure/vacuum relieving.

10.3.4 The open ends of air pipes to oil fuel tanks and cofferdams adjacent to these tanks are to be situated where no danger will be incurred from issuing oil or vapour when the tank is being filled and each opening is to be provided with a wire gauze diaphragm of incorrodible material.

Section 11 Scuppers and sanitary discharges

11.1 General

11.1.1 All exposed decks and enclosed spaces are to be provided with efficient means of drainage.

11.1.2 Sanitary discharges may be led to suitable sanitary tanks or led overboard, provided the spaces to be drained are above the load waterline in any condition of list or trim.

11.1.3 Overboard discharges are to comply with the requirements of Pt 5, Ch 11,2.5 and Ch 11,3.

11.1.4 Scuppers and discharges should not normally pass through oil fuel tanks. Where unavoidable, the arrangements are to be submitted for approval.

11.2 Scantlings

11.2.1 Scuppers and discharge pipes which pass through the shell below the load waterline are to have a thickness, t, not less than $t = 0{,}042\delta_p + 6{,}5$ mm,

where

δ_p is the internal diameter of the pipe in mm, but need not exceed 12,5 mm.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all types of ships covered by Part 4, and requirements are given for rudders, fixed and steering nozzles, steering gears, bow and stern thrust unit structure, and anchoring and mooring equipment.

1.1.2 The requirements of this Chapter are based on the assumption of heavy traffic on relatively narrow waterways through densely populated areas. When ships are intended to be used on waterways with service conditions different from this, they will receive special consideration.

1.1.3 Attention is also drawn to additional requirements of National or International Authorities, e.g. 'Inspection Regulations' of the C.C.N.R. with respect to steering capabilities and requirements for anchoring and mooring equipment.

1.2 Navigation in ice

1.2.1 Where an ice class notation is included in the class of a ship, additional requirements are applicable as detailed in Ch 9,3. The requirements for rudders and sternframes are also applicable to nozzles.

■ *Section 2* Rudders

2.1 General

2.1.1 Requirements are given in this Section for double and single plate rudders and also for certain types of higher efficiency rudders.

2.1.2 The scantlings of flanking rudders (rudders fitted forward of the propeller to improve steering when navigating astern) are to be in accordance with the requirements for rudders fitted abaft the propeller. However, the scantlings are to be not less than required for an astern speed equal to the normal service speed ahead. This type of rudder is to be provided with stops at a maximum angle of helm of 45°.

2.1.3 The scantlings of a bow rudder are to be in accordance with the requirements for rudders out of the propeller slip stream applying the maximum speed, ahead or astern, at which the rudder will be used or half the service speed, whichever is the greater. Efficient arrangements are to be provided for locking the rudder in the centreline position when not in use, *see* Pt 5, Ch 15,1.6.4.

2.1.4 Rudder systems of special design will be considered on the basis of these Rules and full details on the loadings of these rudders are to be given; model tests may be required to support the calculations.

2.1.5 Rudders are to be efficiently supported in the ship's structure by means of suitable carriers in the steering gear flat, or in the solepiece gudgeons. Where the weight of the rudder is supported by carrier bearings, the structure in way is to be adequately strengthened and the deck plating increased in thickness.

2.1.6 Rudder stocks are to be enclosed by watertight trunks or tubes which are to be fitted with an efficient watertight gland or other approved type of seal when the top of the trunks (steering gear flat) is less than 300 mm above the deepest water line in any trimmed condition.

2.1.7 Arrangements to prevent the rudders from lifting are to be fitted. Their strength and that of the supporting structure is to be such that damage to the steering gear in case of touching bottom is prevented, *see* Pt 5, Ch 15,2.1.2(b).

2.2 Rudder stock and bearings

2.2.1 The scantlings of the rudder stock are to be not less than required by Table 12.2.1.

2.2.2 For rudders having an increased diameter of the rudder stock in way of the rudder, *see* Fig. 12.2.2, the increased diameter is to be maintained to a point as far as practicable above the top of the lowest bearing. This diameter may then be tapered to the diameter required in way of the upper bearing and further to the diameter at tiller. The length of the taper is to be at least three times the reduction in diameter. Particular care is to be taken to avoid the formation of a notch at the upper end of the taper. The design of the upper part of the rudder stock and of the upper rudder stock bearing is to take account of any forces which may be imposed by the steering engine, specially in the case where two or more rudders are activated by one steering engine.

2.2.3 Sudden changes of section or sharp corners in way of the rudder coupling, and shoulders for rudder carriers are to be avoided. Jumping collars are not to be welded to the rudder stock. Keyways in the rudder stock are to have rounded ends and the corners at the base of the keyway are to be radiused.

2.2.4 The design of the lowest bearing is to comply with the requirements of Table 12.2.6.

Table 12.2.1 Rudder stock diameter

Item	Requirement
(1) Basic stock diameter, δ_S, at and below lowest bearing	$\delta_S = 52{,}4 K_R \sqrt[3]{f(V+5{,}6)^2 \times \sqrt{A_R{}^2 x_x{}^2 + N^2}}$ mm
(2) Diameter in way of tiller, δ_{SU}	$\delta_{SU} = \delta_S$ in (1) with $N = 0$ For spade rudders: $\delta_{SU} \geq 0{,}7\delta_S$
Symbols	
f = coefficient dependent on type of rudder profile and rudder angle, *see* Table 12.2.5 k_R = rudder coefficient, *see* Table 12.2.2 x_P = horizontal distance, in metres, *see* Table 12.2.3 A_R = rudder area, in m^2 N = coefficient dependent on ruddersupport arrangement, *see* Table 12.2.4 V = maximum service speed with the ship in the loaded condition, in km/h	
NOTE Where the astern speed is expected to be more than 0,5 x the speed ahead, δ_S will be specially considered.	

Table 12.2.2 Rudder coefficient, k_R

Design criteria	k_R
Rudder in propeller slipstream	0,248
Rudder out of propeller slipstream	0,235
Barge – non-self-propelled	0,226
Symbols	
k_R = rudder coefficient for use in Tables 12.2.1 and 12.2.9	

Table 12.2.3 Position of centre of pressure

Design criteria	Value of x_P to be used in Table 12.2.1
Rectangular rudders	$x_P = (0{,}33x_B - x_L)$ but not less than $0{,}12x_B$
Non-rectangular rudders	x_P as calculated from geometric form (*see* Note) but not less than $\dfrac{0{,}12A_R}{y_R}$
Symbols	
x_B = breadth of rudder, in metres x_L = horizontal distance from leading edge of the rudder, to the pintles, or axle, in metres x_P = horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure, in metres x_S = horizontal length of any rectangular strip of rudder geometric form, in metres y_R = depth of rudder on centreline of stock, in metres A_R = rudder area, in m^2	
NOTE For rectangular strips, the centre of pressure should be assumed to be located $0{,}33x_S$ abaft leading edge of strip.	

Table 12.2.4 Pintle arrangement coefficient, *N*
see Fig. 12.2.1

Support arrangement	Value of N
Two or more pintles, *see* Fig. 12.2.1(c)	$N = 0$
One pintle	$N = A_1 (0{,}67y_1 + 0{,}17y_2)$
No pintle	$N = A_2 (y_1 + 0{,}5y_3)$
Symbols	
y_1, y_2, y_3 = vertical dimensions, in metres, *see* Fig. 12.2.1 A_1, A_2 = rudder areas, in m^2, *see* Fig. 12.2.1 N = coefficient for use in Table 12.2.1	

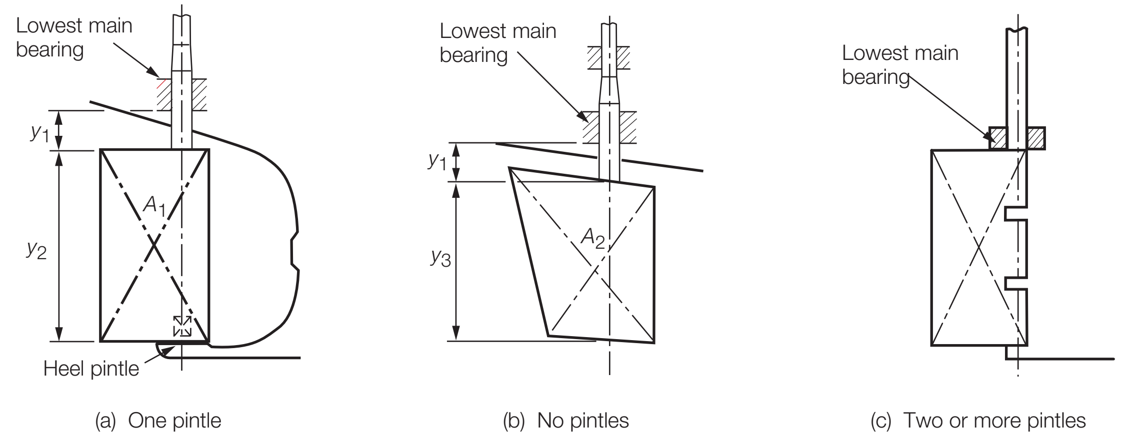


Fig. 12.2.1 Pintle arrangements

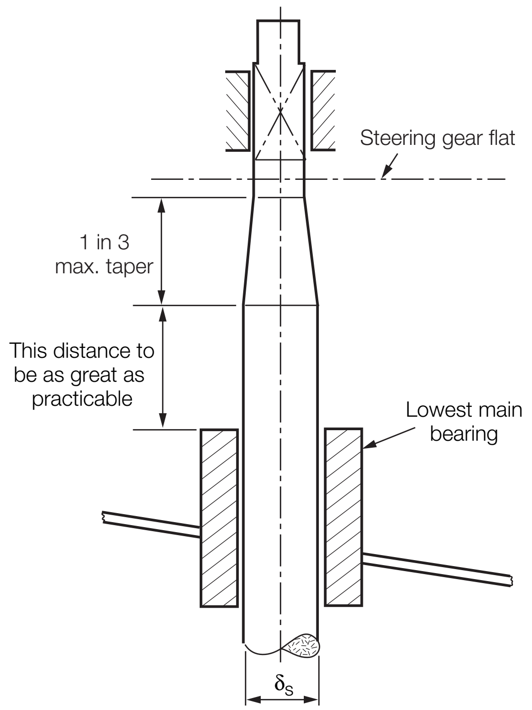


Fig. 12.2.2 Taper of rudder stock

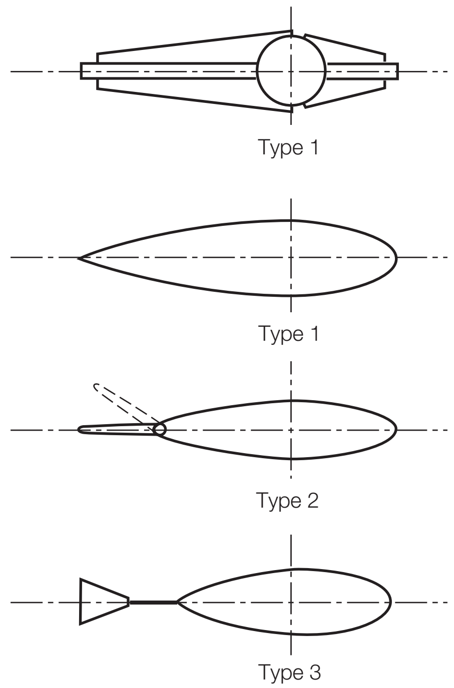


Fig. 12.2.3 Rudder profile types

Table 12.2.5 Rudder coefficient, *f*

Rudder angle	2 x 35°	2 x 45°	2 x 55° or more
Rudder profile Type 1	1,0	1,23	1,43
Rudder profile Type 2	1,60	1,97	—
Rudder profile Type 3	1,15	1,42	1,64
Symbols			
Rudder profile Types 1, 2, and 3, *see* Fig. 12.2.3 *f* = rudder coefficient for use in Tables 12.2.1 and 12.2.9. Intermediate values may be obtained by interpolation			

2.2.5 Where liners are fitted to rudder stocks or pintles, they are to be shrunk on or otherwise efficiently secured. If liners are to be shrunk on, the shrinkage allowance is to be indicated on the plans. Where liners are formed by stainless steel weld deposit, the stocks and pintles are to be of weldable quality steel, and details of the procedure are to be submitted, *see also* 2.2.6.

2.2.6 Where it is proposed to use stainless steel liners and bushes for rudder stock and/or pintle bearings, the chemical composition and mechanical properties are to be submitted for approval. Materials for bushes and liners are to have a suitable difference in hardness. Synthetic rudder bearing materials are to be of a type approved by Lloyd's Register (hereinafter referred to as LR).

Table 12.2.6 Lowest main bearing requirements

Item	Requirements	
Lowest main bearing	Depth z_B, in mm	
	$1{,}5\delta_S \geq z_B \geq 1{,}0\delta_S$ For spade rudders: $1{,}5\delta_S \geq z_B \geq 1{,}3\delta_S$	
Bearing pressure (on the projected area of the lowest main bearing), where the area is to be taken as the projected length x diameter	Bearing material	Maximum pressure, in N/mm^2 (kgf/cm^2)
	Metal	6,87 (70,0)
	Synthetic	4,41 (45,0)
	Lignum Vitae	2,45 (25,0)
Clearance in lowest main bearing on the diameter (note should be taken of the manufacturer's recommended clearances, particularly where bush material requires pre-soaking)	Bearing material	Clearance, in mm
	Metal, *see* Note	$0{,}001\delta_S + 1{,}0$
	Synthetic	$0{,}002\delta_S + 1{,}0$ but not less than 1,5
Symbols		
z_B = depth of lowest bearing, in mm δ_S = basic stock diameter, given by Table 12.2.1, in mm		
NOTE For bearings which are pressure lubricated, the clearance must be restricted to enable the pressure to be maintained.		

2.3 Rudder construction – Doubled plated

2.3.1 The scantlings of a double plated rudder are to comply with Table 12.2.7, but the thickness of the rudder plating may require to be increased in way of the rudder coupling and the heel pintle.

Table 12.2.7 Double plated rudder construction

Item	Requirements
(1) Side plating	$t = 3y_W (1{,}45 + 0{,}1\sqrt{\delta_S}) + 2$ mm
(2) Webs – vertical and horizontal	As (1) above
(3) Top and bottom plates	As (1) above, using y_W = maximum rudder width, in metres, at top or bottom, but not less than 0,9 m
(4) Nose plates	$t_N \geq 1{,}25t$ from (1)
(5) Mainpiece – fabricated rectangular, *see* Note	Breadth and width $\geq \delta_S$ $t_M = 5 + 0{,}56\sqrt{\delta_S}$ mm Minimum fore and aft extent of side plating = $0{,}2x_B$ Stress due to bending < 9 kgf/mm^2
(6) Mainpiece – tubular, *see* Note	Inside diameter $\geq \delta_S$ t_M as for (5) Side plating as for (1) Bending stress as for (5)
Symbols	
t = thickness, in mm t_M = thickness of side plating and vertical webs forming mainpiece or of tubular mainpiece where fitted, in mm t_N = thickness of nose plate, in mm y_W = vertical spacing, in metres, of the horizontal webs, but is not to exceed 0,9 m x_B = breadth of rudder on centreline of stock, in metres δ_S = basic stock diameter, given by Table 12.2.1, in mm	
NOTE The section modulus of the lower third of the mainpiece may be gradually reduced to two-thirds the section modulus required by this Table. For spade type rudders, *see* 2.3.3.	

2.3.2 Adequate hand or access holes are to be arranged in the rudder plating in way of the pintles as required and the rudder plating is to be reinforced locally in way of these openings. Continuity of the modulus of the rudder mainpiece is to be maintained in way of the openings.

2.3.3 In order to minimize the risk of damage to the steering gear, *see* Pt 5, Ch 15,2.1.2(b), it is recommended that the lower third part of spade type rudders, *see* Fig. 12.2.1(b), be constructed without mainpiece or vertical webs. The section modulus of the mainpiece may be gradually tapered down to 50 per cent of the value required by Table 12.2.7.

2.3.4 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds on to flat bars on the webs. The slots are to have a minimum length of 75 mm and in general, a minimum width of twice the side plating thickness or 20 mm, whichever is the greater. The ends of the slots are to be rounded. The space between the slots is not to exceed 150 mm. Alternatively, the side plating may be fitted in panels, fillet welded all round either direct on to webs of increased thickness or on to flat bars on the webs.

2.3.5 Double plate rudders are to be efficiently coated internally and means for draining the rudder are to be provided.

2.3.6 For the testing of rudders, *see* Table 1.7.2 in Chapter 1.

2.3.7 Where the fabricated mainpiece of a spade rudder is connected to the horizontal coupling flange by welding, a full penetration weld is required.

2.4 Rudder construction – Single plated

2.4.1 The scantlings of a single plated rudder are to be not less than required by Table 12.2.8.

Table 12.2.8 Single plate rudder construction

Item and parameter	Requirements
Blade thickness	The greater of: $t = 5 + 0{,}02\delta_S + 10y_W$ mm $t = 10$ mm
Section modulus of arms	$Z = 0{,}25 \times y_W^2 \times x_W(V + 5{,}6)^2$ cm^3
Diameter of mainpiece	Diameter = δ_S mm, *see* Note to Table 12.2.7
Symbols	
t = thickness, in mm x_W = breadth of rudder blade aft of stock, in metres y_W = vertical spacing, in metres, of the arms, but is not to exceed 0,9 m V = ship's speed, in km/h Z = section modulus, in cm^3 δ_S = basic stock diameter, given by Table 12.2.1, in mm.	

2.4.2 For spade type rudders, *see* 2.3.3.

2.4.3 Rudder arms are to be efficiently attached to the mainpiece.

2.5 Rudder couplings

2.5.1 Rudder coupling design is to be in accordance with Table 12.2.9. Conical couplings will be specially considered.

Table 12.2.9 Rudder couplings to stock

Arrangement	Parameter	Requirements: Horizontal coupling	Requirements: Vertical coupling
Bolted couplings	n	≥ 6	≥ 8
	δ_b	$\dfrac{0,65\delta_S}{\sqrt{n}}$	$\dfrac{0,81\delta_7}{\sqrt{n}}$
	m	$0,00071n\ \delta_S\ \delta_b^2$	$0,00043\delta_S^3$
	t_f	$\geq \delta_b$ (*see* Note 1)	δ_b
	α_{max} (*see* Note 2)	$(53,82 - 35,29k_1)\ \dfrac{\delta_s^3}{P_L\ h\ 10^3} - \left(1,8 - 6,3\ \dfrac{R}{\delta_s}\right) \dfrac{t_f\ t_{fa}}{t_{fa}}$	–
	$\alpha_{as\ built}$ (*see* Note 2)	$\leq \alpha_{max}$	–
	w_f	$0,67\delta_b$	$0,67\delta_b$

Symbols

h = vertical distance between the centre of pressure and the centre point of the palm radius, R, in metres, *see* Fig. 12.2.4(a)
k_1 = the greater of k_s and k_f
k_f = upper coupling flange material factor
k_s = rudder stock material factor
m = first moment of area of bolts about centre of coupling, in cm^3
n = number of bolts in coupling
t_f = minimum thickness of coupling flange, in mm
t_{fa} = as built flange thickness, in mm
w_f = width of flange material outside the bolt holes, in mm
R = palm radius between rudder stock and connected flange, not smaller than $\dfrac{\delta_s}{10}$, in mm

$\alpha_{as\ built}$ = stress concentration factor for as built scantlings
$= \dfrac{0,73}{\sqrt{\dfrac{R}{\delta_s}}}$
α_{max} = maximum allowable stress concentration factor
δ_b = diameter of coupling bolts, in mm
δ_S, δ_{SU} = rudder stock diameters as defined in Table 12.2.1
P_L = lateral force acting on the rudder, in N, is to be calculated for both ahead and astern conditions. The greater of the two values is to be used
P_L = $117,5k_R\ f\ (V + 5,6)^2\ A_R$ N
k_R = rudder coefficient, *see* Table 12.2.2
f = rudder coefficient, *see* Table 12.2.5
V = maximum service speed with the ship in the loaded condition, in km/h
A_R = rudder area, in m^2

NOTES
1. For spade rudders with horizontal coupling, t_f is not to be less than $0,25\delta_S$.
2. This requirement is applicable only for spade rudders with horizontal couplings, *see* Fig. 12.2.4.

2.5.2 For rudders with horizontal coupling arrangements, where the upper flange is welded to the rudder stock, a full penetration weld is required and its integrity is to be confirmed by non-destructive examination. Such rudder stocks are to be subjected to a furnace post-weld heat treatment (PWHT) after completion of all welding operations. For carbon or carbon manganese steels, the PWHT temperature is to be not less than 600ºC.

2.5.3 The connecting bolts for coupling the rudder to the rudder stock are to be positioned with sufficient clearance to allow the fitting and removal of the bolts and nuts without contacting the palm radius, R, *see* Fig. 12.2.4(a). The surface forming the palm radius is to be free of hard and sharp corners and is to be machined smooth to the Surveyor's satisfaction. The surface in way of bolts and nuts is to be machined smooth and to the Surveyor's satisfaction.

2.5.4 For spade rudders fitted with a fabricated rectangular mainpiece, the mainpiece is to be designed with its forward and aft transverse sections at equal distances forward and aft of the rudder stock transverse axis, *see* Fig. 12.2.4(b).

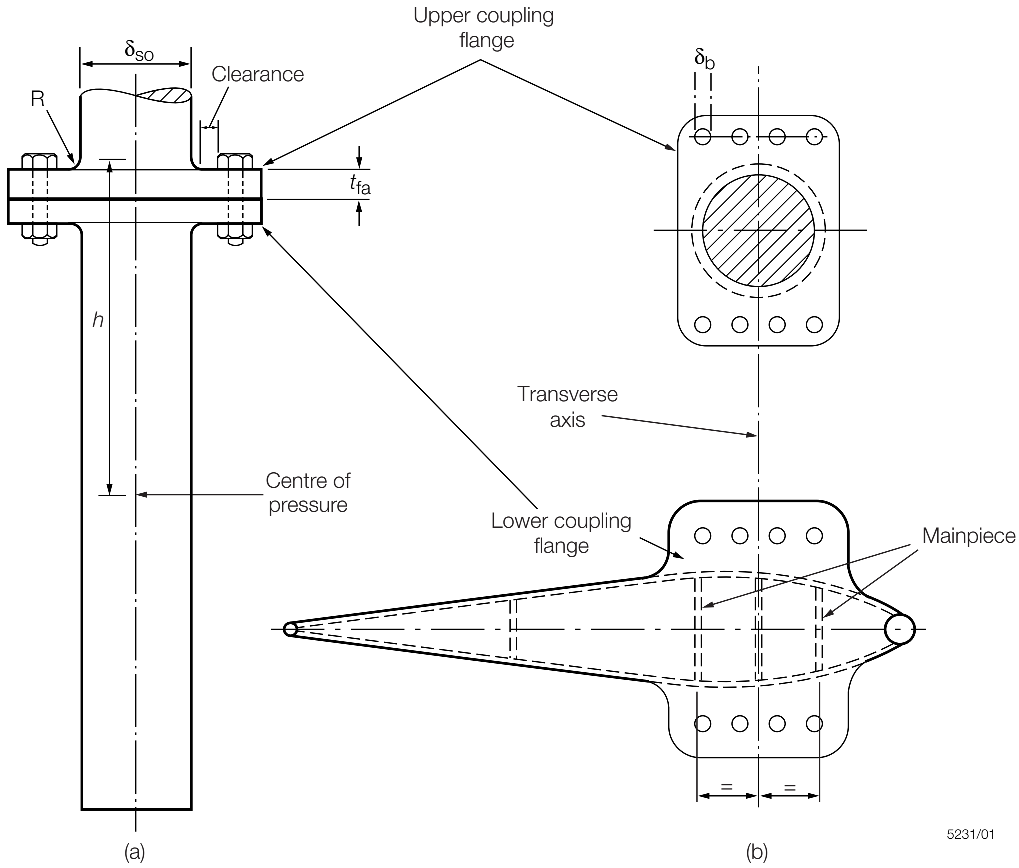


Fig. 12.2.4 Rudder stock connection

2.6 Pintles

2.6.1 Rudder pintles and their bearings are to comply with the requirements of Table 12.2.10.

2.6.2 Where coned pintles are fitted special attention is to be paid to the fit of the pintle taper into its housing. The pintle taper is not to exceed one in six on the diameter, but to facilitate removal of the pintles it is recommended that the taper be not less than 1 in 12 on the diameter.

Table 12.2.10 Pintle requirements

Item	Requirements	
(1) Pintle diameter (measured outside liner if fitted)	$\delta_{PL} = 31 + 2{,}25V\sqrt{A_{PL}}$ mm where for single pintle rudders: $A_{PL} = \dfrac{A_R\, C_{CP}}{C_{PL}}$ m^2 and for rudders with two or more pintles: $A_{PL} = \dfrac{A_R}{N_{PL}}$ m^2	
(2) Bearing length	$z_{PB} \geq 1{,}2\delta_{PL}$	
(3) Gudgeon thickness in way of pintle (measured outside bush if fitted)	$b_G \geq 0{,}5\delta_{PL}$	
(4) Recommended pintle clearance (note should be taken of the manufacturer's recommended clearances, particularly where bush material requires pre-soaking)	Bearing material	Clearance, in mm (on diameter)
	Metal	$0{,}001\delta_{PL} + 1{,}0$
	Synthetic	$0{,}002\delta_{PL} + 1{,}0$ but not less than 1,5
Symbols		
b_G = thickness of gudgeon material in way of pintle, in mm z_{PB} = pintle bearing length, in mm A_{PL} = rudder area supported by the pintle, in m^2 C_{CP}, C_{PL} = dimensions, in metres, as indicated in Fig. 12.2.5 N_{PL} = number of pintles on the rudder V = ship speed, in km/h, but not less than 12 km/h δ_{PL} = pintle diameter, in mm A_R = rudder area, in m^2		
NOTE Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.		

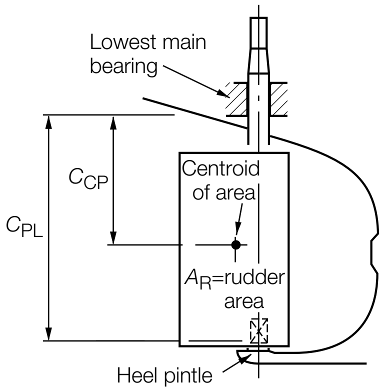


Fig. 12.2.5 Dimensions for pintle requirements

■ *Section 3* Fixed and steering nozzles

3.1 General

3.1.1 The requirements for scantlings for fixed and steering nozzles are given, for guidance only, in 3.2 to 3.4 and Table 12.3.1.

Table 12.3.1 Nozzle construction requirements

Item	Requirements
(1) Nozzle numeral	$N_N = 0{,}01P\sigma_P$, *see* Note 1 ($N_N = 0{,}00736H\sigma_P$)
(2) Shroud plating in way of propeller blade tips	$t_s = 8{,}0 + 0{,}14N_N$ mm, but not less than 10,0 mm for mild steel
(3) Shroud plating, clear of blade tips, flare and cone plating, wall thickness of leading and trailing edge members	$t_p \geq 8{,}0$ mm
(4) Webs and ring webs	As item (3) except in way of headbox and pintle support $t_w = t_s + 4{,}0$ mm
(5) Nozzle stock	Combined stresses in stock at lower bearing $\leq 92{,}7$ N/mm^2 (9,45 kgf/mm^2) Torsional stress in upper stock $\leq 62{,}0$ N/mm^2 (6,3 kgf/mm^2)
(6) Solepiece and strut	Bending stresses not to exceed 7,0 N/mm^2 (7,1 kgf/mm^2)
Symbols	
t_p = thickness of plating, in mm t_s = thickness of shroud plating in way of propeller tips, in mm t_w = thickness of webs and ring webs in way of headbox and pintle support, in mm N_N = a numeral dependent on the nozzle requirements P = power transmitted to the propellers, in kW (H = power transmitted to the propellers, in shp) σ_P = diameter of the propeller, in metres	
NOTES 1. Nozzle for engine powers of more than 2000 shp (1472 kW) and having diameters of more than 2,5 will be specially considered. 2. Thicknesses given are for mild steel. A 2 mm reduction in thickness will be considered for certain stainless steels, however, the minimum thickness is 8 mm.	

3.2 Nozzle structure

3.2.1 For basic scantlings of the structures, *see* Table 12.3.1, in association with Fig. 12.3.1.

3.2.2 The shroud plating in way of the propeller tips is to be carried well forward and aft of this position, due allowance being made on steering nozzles for the rotation of the nozzle in relation to the propeller.

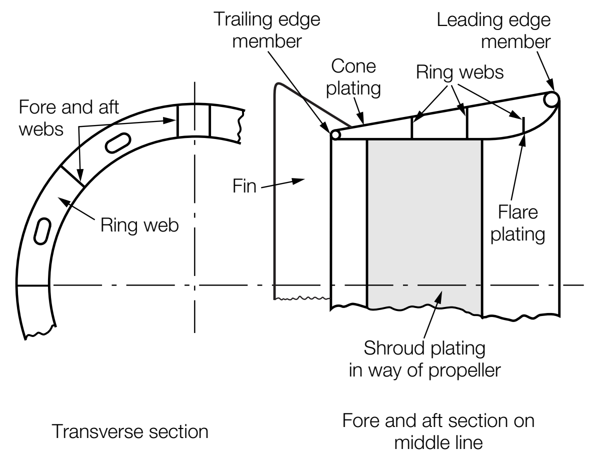


Fig. 12.3.1 Basic nozzle structure

3.2.3 Fore and aft webs are to be fitted between the inner and outer skins of the nozzle. Both sides of the headbox and pintle support structure are to be connected to fore and aft webs of increased thickness. For thicknesses, *see* Table 12.3.1.

3.2.4 The transverse strength of the nozzle is to be maintained by the fitting of ring webs. Two ring webs are, generally, to be fitted. Where ring webs are increased in thickness in way of the headbox and pintle support structure in accordance with Table 12.3.1, the increased thickness is to be maintained at the adjacent fore and aft web.

3.2.5 Local stiffening is to be fitted in way of the top and bottom supports which are to be integrated with the webs and ring webs. Continuity of bending strength is to be maintained in these regions.

3.2.6 Plating thickness of fabricated fins should be not less than the cone plating, and the fin should be adequately reinforced.

3.2.7 Care is to be taken in the manufacture of the nozzle to ensure its internal preservation and watertightness. The preservation and testing are to be as required for rudders, *see* 2.3.5 and Table 1.7.2 in Chapter 1.

3.3 Nozzle stock and solepiece

3.3.1 Stresses, derived using the maximum side load on the nozzle and fin acting at the assumed centre of pressure, are not to exceed the values given in Table 12.3.1, in both the ahead and astern conditions.

3.4 Ancillary items

3.4.1 The diameter of pintles, and the diameter and first moment of area about the stock axis of coupling bolts, are to be derived from 2.5 and 2.6.

3.4.2 Suitable arrangements are to be provided to prevent the steering nozzle from lifting.

■ *Section 4* Bow and stern thrust unit structure

4.1 Unit wall thickness

4.1.1 The wall thickness of the unit is, in general, to be in accordance with the manufacturer's practice, but is to be not less than either the thickness of the surrounding shell plating plus 10 per cent or 9 mm, whichever is greater.

4.2 Framing

4.2.1 The unit is to be framed to the same standard as the surrounding shell plating.

4.2.2 The unit is to be adequately supported and stiffened.

■ *Section 5* Equipment

5.1 Scope

5.1.1 The anchoring equipment required by this Section for the various ship types is based on the ship's Equipment Number, *see* 5.3.1, in association with standard environmental criteria and conditions detailed in 5.2.3.

5.1.2 When ships are intended to operate under environmental conditions differing from those detailed in 5.2.2, the anchoring and mooring equipment will be specially considered and modified to suit the actual conditions. *See* 5.4.2.

5.2 General

5.2.1 To entitle a ship to the figure **1** in its character of classification, equipment is to be provided as follows:

(a) either in accordance with the requirements of Table 12.5.2; or
(b) with modified anchoring and mooring equipment approved under 5.1.2; or
(c) in accordance with established National or International Regulations and where agreed by the Committee, e.g. 'Inspection Regulations' of the C.C.N.R.

5.2.2 Ships not equipped for towing are not required to be equipped with a towline.

5.2.3 The anchors, cables, towlines and mooring wires required by Table 12.5.1 are to comply with Table 12.5.2, except where stated. Table 12.5.2 is based on the following conditions:

(a) Current of river, maximum 8 km/h.
(b) Fall of river, not exceeding 0,3 m/km.
(c) Anchoring grounds being such that an approved standard type anchor has a holding power in the particular soil not less than six times its weight.

5.2.4 Where the Committee has agreed that anchoring and mooring equipment need not be fitted in view of the particular service of the ship, the character letter **N** will be assigned. *See also* Pt 1, Ch 2,2.2.2.

5.2.5 Where the ship is intended to perform its primary designed service function only while it is anchored, moored, towed or linked, the character letter **T** will be assigned. *See also* Pt 1, Ch 2,2.2.2.

5.2.6 For classification purposes, the character figure **1**, or either of the character letters **N** or **T**, is to be assigned.

Table 12.5.1 Equipment requirements

Ship type	Required equipment					
	Bow anchors	Chain cables	Stern anchor	Stern anchor cable or wire	Towline	Mooring wires
Self-propelled: All ship types as per Part 4 except passenger ships and tugs	According to Table 12.5.2, *see* 5.4.2	According to Table 12.5.2	According to Table 12.5.2, *see* 5.4.3 and 5.4.5	According to Table 12.5.2	According to Table 12.5.2	According to Table 12.5.2
Self-propelled: Passenger ships	According to Table 12.5.2	According to Table 12.5.2	*See* 5.4.4	*See* 5.4.4	According to Table 12.5.2	According to Table 12.5.2
Tugs: Towing only	75% of mass according to Table 12.5.2, *see* 5.4.7	According to Table 12.5.2, *see* 5.4.7	Not required	Not required	*See* 5.4.8	According to Table 12.5.2
Tugs: Equipped for towing and pushing	75% of mass according to Table 12.5.2, *see* 5.4.7	According to Table 12.5.2, *see* 5.4.7	*See* 5.4.5	*See* 5.4.5	*See* 5.4.8	According to Table 12.5.2
Tugs: Pushing only (pusher tugs)	Not required	Not required	*See* 5.4.6	*See* 5.4.6	According to Table 12.5.2	According to Table 12.5.2
Self-propelled: (operating only in areas where current speed of water never exceeds 2 km/h (canals and similar waterways)), cargo ships, tankers, oil tankers, chemical tankers, ferries and ro/ro ships, liquefied gas tankers, passenger ships	Mass 50% of value indicated in Table 12.5.2, *see* 5.4.2	Breaking strength according to mass of anchor	Mass 50% of value indicated in Table 12.5.2	Length of cable according to Table 12.5.2, Note 4 Breaking strength according to mass of anchor	Length of cable according to Table 12.5.2, Note 5 Breaking strength 50% of value indicated in Table 12.5.2	Length of cable according to Table 12.5.2, Notes 6 and 7 Breaking strength 50% of value indicated in Table 12.5.2
Non-propelled: (to be towed, pushed or carried alongside another vessel), cargo ships, all tankers, liquefied gas tankers and pontoons	According to Table 12.5.2, *see* 5.4.2	According to Table 12.5.2, *see* 5.4.2	According to Table 12.5.2, *see* 5.4.9 and 5.4.10	According to Table 12.5.2	According to Table 12.5.2	According to Table 12.5.2
Pushbarges: (except lash barges)	According to Table 12.5.2, *see* 5.4.2	According to Table 12.5.2, *see* 5.4.2	Not required	Not required	According to Table 12.5.2	According to Table 12.5.2

Table 12.5.2 Equipment – Anchors, anchor cables, towlines and mooring lines

Equipment Number		Stockless bower anchors, *see* Note 1		Bower anchor cable or wire, *see* Note 2	Stockless stern anchors, *see* Note 3		Stern anchor cable or wire, *see* Note 4	Towline, *see* Note 5	Mooring lines, *see* Notes 6 & 7
Exceeding	Not exceeding	Mass of anchor, in kg	Mass of HHP anchor, in kg	Minimum breaking strength, in kN	Mass of anchor, in kg	Mass of HHP anchor, in kg	Minimum breaking strength, in kN	Minimum breaking strength, in kN	Minimum breaking strength, in kN
0	2	12	9	4,2	—	—			
2	4	23	17	7,9	—	—			
4	6	35	26	12,1	—	—			
6	8	46	35	15,8	—	—			
8	10	58	44	20,0	—	—			14
10	12	69	52	23,7	—	—			17
12	14	81	61	27,9	—	—			20
14	17	98	74	33,7	—	—			24
17	20	115	86	40	—	—			28
20	25	144	108	50	—	—		56	36
25	30	173	130	60	—	—		67	43
30	40	230	173	79	115	86	40	90	57
40	50	288	216	99	144	108	50	112	72
50	60	345	259	119	173	130	60	134	86
60	70	403	302	139	202	152	70	157	100
70	80	460	345	158	230	173	79	179	115
80	90	518	389	178	259	194	89	202	129
90	100	575	431	198	288	216	99	224	143
100	110	633	475	218	317	238	109	231	158
110	120	690	518	237	345	259	119	238	172
120	130	735	551	253	368	276	127	245	182
130	140	779	584	268	390	293	134	252	187
140	150	824	618	283	421	309	142	259	192
150	160	868	651	299	434	326	150	266	197
160	170	913	685	314	457	343	157	272	202
170	180	958	719	329	479	359	165	279	208
180	190	1002	752	345	501	376	173	286	213
190	200	1047	785	360	524	393	180	293	218
200	210	1091	818	375	546	410	188	300	223
210	220	1136	852	391	568	426	196	307	228
220	230	1181	886	406	591	443	203	314	233
230	240	1226	920	421	613	460	211	321	238
240	250	1270	953	437	635	476	219	328	244
250	260	1314	986	452	657	493	226	335	249
260	270	1359	1019	467	680	510	234	342	254
270	280	1404	1053	483	702	527	248	349	259
280	290	1448	1086	498	724	543	249	355	264
290	300	1493	1120	513	746	560	257	362	269
300	310	1538	1154	529	769	577	265	369	274
310	320	1582	1187	544	791	593	272	376	279
320	330	1627	1220	559	814	611	280	382	285
330	340	1672	1254	575	836	627	288	389	290
340	350	1716	1287	590	858	644	295	396	295
350	360	1761	1321	605	880	660	303	402	300

NOTES
1. Two stockless bower anchors are required, but *see* 5.4.2.
2. The length of short or stud link chain cable for each bower anchor is to be not less than L + 10 m with a minimum of 40 m and a maximum of 60 m. Where wires are used, the length is to be 1,25 times that required for the chain cable. The minimum breaking strength of the chosen diameter and grade of short or stud link chain cable or wire is to be in accordance with 5.6.3 and 6.6.4.
3. For self propelled ships, *see* 5.4.3 and 5.4.5. For non-propelled ships being towed, *see* 5.4.8.
4. The length of cable for each stern anchor, on ships having an Equipment Number exceeding 30, is to be not less than 40 m.
5. The length of the towline is to be not less than given by the following formulae, as appropriate:
   (a) L + 75 m for ships having an Equipment Number between 20 and 160.
   (b) L + 100 m, for ships having an Equipment Number above 160.
   See also 6.2.1.
6. Two mooring lines are required for ships having an Equipment Number below 100 and three for ships having larger values.
7. The length of each wire in the mooring lines is to be not less than 2,5L, but need not be more than 100 m.

5.3 Calculation of Equipment Number

5.3.1 The equipment of anchors and chain cables is based on an 'Equipment Number' which is to be calculated as follows:

$$\text{Equipment Number} = \Delta^{2/3} + \frac{A}{10}$$

where

Δ = moulded displacement to the deepest load waterline, in tonnes

A = area, in m^2, in profile view of the hull above the deepest load waterline within the Rule length of the ship and of superstructures and deck houses including trunks and hatchcoamings, which are within the Rule length of the ship, *see also* 5.3.2. When calculating this area the shear and trim are to be ignored.

5.3.2 Screens and bulwarks more than 800 mm in height are to be regarded as parts of houses when determining *A*. Where a screen or bulwark is of varying height, the portion to be included is to be that length, the height of which exceeds 800 mm.

5.4 Equipment for particular ship types

5.4.1 The anchors, chain cables, towlines and mooring for particular ship types are to comply with Table 12.5.1 and 5.4.2 to 5.4.10 as applicable.

5.4.2 Self-propelled ships, except passenger ships and tugs operating in areas where the water current speed exceeds 2 km/h, and also non-propelled ships and push-barges, except lash barges, are to comply with the following:

(a) Ships with a sharp stem are to be equipped with two bow anchors of a mass according to Table 12.5.2.

(b) Ships without a sharp stem may be equipped with two bow anchors of a mass according to Table 12.5.2 or with one bow anchor of a mass equal to twice the mass of a bower anchor according to Table 12.5.2 with the appropriate chain cable or steel wire.

5.4.3 Self-propelled ships, except passenger ships and tugs, operating on rivers, where, in view of their length, they cannot safely turn for anchoring with the bow in an upstream direction are to be fitted with a stern anchor of a mass equal to twice the mass of a stern anchor according to Table 12.5.2 with the appropriate chain cable or steel wire.

5.4.4 Passenger ships operating on rivers where, in view of their length, they cannot safely turn for anchoring with the bow in an upstream direction are to be fitted with a stern anchor and chain cable or steel wire according to Table 12.5.2.

5.4.5 Self-propelled ships and tugs intended and equipped for pushing and/or carrying alongside barges operating on rivers, where, in view of the length of the train, they cannot safely turn for anchoring with the bow in an upstream direction are to be equipped with stern anchor(s) as required for pusher tugs by 5.4.6.

5.4.6 Pusher tugs are to be provided with two stern anchors and the chain cable for each anchor is to have a length of 60 m and a breaking strength in accordance with 5.6.3. The mass of the stern anchors to be provided depends upon the train to be pushed and on the environmental conditions. For the standard conditions, *see* 5.2.3, the mass of each stern anchor is to be:

$$0{,}11\Delta_v + 250 \text{ kg}$$

where

Δ_v = displacement of the complete train, excluding the pusher tug, in m^3

5.4.7 Tugs intended and equipped for towing may be fitted with one or two bow anchors. Where only one bow anchor is fitted it is to have a mass equal to twice the mass required for bow anchors according to Table 12.5.2 and connected to the appropriate chain cable or steel wire.

5.4.8 Tugs intended for towing other ships and having towlines for that purpose on board need not be supplied with a towline in accordance with Table 12.5.2.

5.4.9 Non-propelled ships intended to be towed and having an Equipment Number exceeding 120 are to be fitted with two stern anchors and chain cables or steel wires according to Table 12.5.2. Alternatively, one stern anchor having a mass equal to twice the mass required according to Table 12.5.2 may be fitted together with the appropriate chain cable or steel wire.

5.4.10 Non-propelled ships intended to be towed and having an Equipment Number less than 120 are to be fitted with a stern anchor of mass in accordance with Table 12.5.3.

Table 12.5.3 Stern anchor for non-propelled ships to be towed

Equipment Number		Mass of stern anchor, in kg
Exceeding	Not exceeding	
30	40	115
40	50	144
50	60	173
60	70	242
70	80	276
80	90	310
90	100	402
100	110	443
110	120	483

5.5 Anchors

5.5.1 Anchors are to be of an approved design and of a type suitable for the intended service. The design of all anchor heads is to be such as to minimize stress concentrations and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

5.5.2 The mass of each bower anchor given in Table 12.5.2 is for anchors of equal mass. The masses of individual anchors may vary by a maximum of ±7 per cent of the masses given in the Table, provided that the total mass of the anchors is not less than would have been required for anchors of equal mass. Where the maximum current expected in service differs considerably from 8 km/h, the anchor weight required by Table 12.5.2 is to be increased by multiplying by the factor:

$$\left(\frac{\text{Current speed, in km/h}}{8}\right)^{1,825}$$

when the current exceeds 8 km/h and may be reduced by the factor:

$$\sqrt{\frac{\text{Current speed, in km/h}}{8}}$$

when the current is less than 8 km/h, but is not to be taken less than 2 km/h.

5.5.3 The mass of the head, including pins and fittings, of an ordinary stockless anchor is to be not less than 60 per cent of the total mass of the anchor.

5.5.4 When stocked bower or stream anchors are to be used, the mass 'ex stock' is to be not less than 80 per cent of the mass given in Table 12.5.2 for ordinary stockless bower anchors. The mass of the stock is to be 25 per cent of the total mass of the anchor, including the shackle, etc., but excluding the stock.

5.5.5 When anchors of a design approved for the designation 'High Holding Power' (HHP) are used, the mass of each such anchor may be 75 per cent of the mass given in Table 12.5.2 for ordinary stockless bower anchors. For approval as an HHP anchor, *see* Pt 3, Ch 13,7 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

5.5.6 Where equipment is being provided in accordance with applicable National or International Regulations, as per 5.2.1(c), the reductions in mass as specified in these Regulations for approved type HHP anchors, may also be applied.

5.6 Chain cables

5.6.1 Chain cables may be either short link or stud link and of mild steel or special quality steel in accordance with the requirements of Chapter 10 of LR's *Rules for Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) and are to be graded in accordance with Table 12.5.4.

5.6.2 In conjunction with HHP anchors only Grade U2 or ISO Grade 40 chain cable is to be used, except that, when desired by Owners, for HHP anchors having a mass of 300 kg or less, Grade U1 chain cable may be used provided the diameter of Grade U1 cable required in accordance with 5.6.3 is increased by five per cent.

Table 12.5.4 Grades of chain cables

Grade	Material	Tensile strength	
		N/mm^2	(kgf/mm^2)
U1	Mild steel	300–490	(31–50)
U2(a)	Special quality steel (wrought)	490–690	(50–70)
U2(b)	Special quality steel (cast)	490–690	(50–70)

5.6.3 The breaking strength of the chain cable in kN (tonne-f) is to be not less than 0,343 times (0,035 times) the mass of the anchor in kg, or in the case of HHP anchors not less than 0,458 times (0,0467 times) the actual mass in kg of the HHP anchor.

5.6.4 The form and proportions of links and shackles are to be in accordance with Chapter 10 of LR's Rules for Materials and/or with International Standard ISO/R 1834 – 1971, ISO/R 1835 – 1971, ISO/R 1836 – 1971, ISO/1704 – 1973 or DIN 766A.

5.6.5 When desired by the Owners, steel wires may be used instead of chain cables. Steel wires are to have a breaking strength not less than that required for chain cables and their length is to be not less than 25 per cent in excess of the length required for chain cable in Table 12.5.1 or Table 12.5.2.

5.7 Towlines and mooring lines

5.7.1 Towlines and mooring lines are to comply with Table 12.5.1 and Table 12.5.2. They may be of wire, natural fibre or synthetic fibre. The diameter, construction and specification of wire or natural fibre towlines are to comply with the requirements of Chapter 10 of LR's Rules for Materials. Where it is proposed to use synthetic fibre ropes, the size and construction will be specially considered. *See also* 5.2.1.

5.7.2 The lengths of individual mooring lines in Table 12.5.2 may be reduced by up to 10 per cent of the Table length, provided that the total length of mooring lines is not less than would have resulted had all lines been of equal length.

5.7.3 Means are to be provided to enable mooring lines to be efficiently secured on board ship by an adequate number of suitably placed bollards on either side of the ship.

5.8 Testing of equipment

5.8.1 All anchors and chain cables are to be tested at establishments and on machines recognized by the Committee and under the supervision of LR's Surveyors or other Officers recognized by the Committee, and in accordance with Chapter 10 of LR's Rules for Materials.

5.8.2 Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the anchors and cables are placed on board the ship.

5.8.3 Steel wire and fibre ropes are to be tested as required by Chapter 10 of LR's Rules for Materials.

5.9 Windlasses

5.9.1 The requirements of 5.9.2 to 5.9.5 apply equally to bow and stern anchor winches.

5.9.2 On ships equipped with anchors having a mass of over 50 kg, windlass(es) of sufficient power and suitable for the type and size of chain cable are to be fitted. Arrangements for anchor davits will be specially considered.

5.9.3 The windlasses may be hand or power operated. Hand operated windlasses are only acceptable if the effort required at the handle does not exceed 15 kgf for raising one anchor at a speed of not less than 2 m/min and making about 30 turns of the handle per minute.

5.9.4 A power operated windlass is to be capable of exerting, for a period of not less than 30 minutes, a continuous duty pull of $28d^2$ N ($2{,}8d^2$ kgf) and to raise one anchor with chain cable at a mean speed or not less than 9 m/min. (Note that d is the diameter required for Grade U1 chain cable.)

5.9.5 Winches suitable for operation by hand as well as by external power are to be so constructed that the power drive cannot activate the hand drive.

5.10 Structural requirements

5.10.1 The requirements of 5.10.2 to 5.10.6 apply equally to bow and stern anchoring arrangements.

5.10.2 The windlass is to be efficiently bedded and secured to the deck. The thickness of the deck on way of the windlass is to be increased, and adequate stiffening is to be provided, to the Surveyor's satisfaction.

5.10.3 An easy lead of the cables from the windlass to the anchors and chain locker is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimize the probability of damage to, or snagging of, the cable. They should, in general, be of sufficient strength to withstand a proof load equal to the proof load of the cable passing over them.

5.10.4 Hawse pipes and anchor pockets if fitted are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movement of the anchor being caused by wave action. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary. Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large, radiused faces to minimize the probability of cable links being subjected to high bending stresses. Alternatively, roller fairleads of suitable design may be fitted. Where unpocketed rollers are used, it is recommended that the roller diameter be not less than 11 times the cable diameter. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

5.10.5 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker.

5.10.6 Provision is to be made for securing the inboard ends of the cables to the structure.

Section

1 **General requirements**

■ *Section 1*
General requirements

1.1 General description

1.1.1 A elevating wheelhouse system generally consists of several concentrically mounted slidable columns with the wheelhouse fitted on the top of the innermost column, *see* Fig. 13.1.1. The number of columns normally varies between 2 and 4. The columns are usually square or rectangular. The wheelhouse can be moved up and down by means of one or more (hydraulic) lifting cylinder(s) to reach the desired height. Another configuration may consist of a wheelhouse fitted on a scissor lift, *see* Fig. 13.1.2, or may consist of a wheelhouse suspended by hydraulic jacks. This Chapter mainly deals with elevating wheelhouse systems of the type with the slidable columns. Other systems will be specially considered.

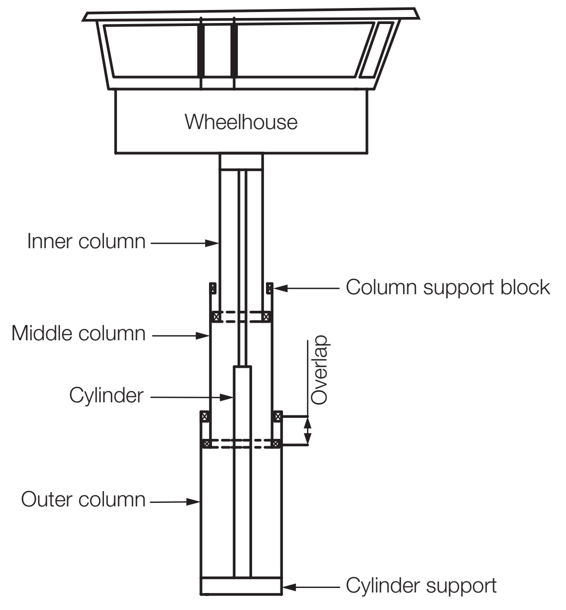


Fig. 13.1.1 General sketch elevating wheelhouse

1.1.2 The forces between the columns are transferred by support/sliding blocks, hereafter referred to as blocks.

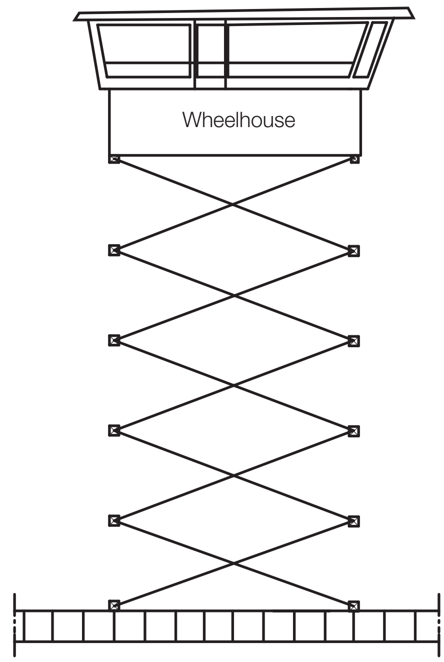


Fig. 13.1.2 Scissor lift

1.1.3 The elevating wheelhouse columns may be integrated into the ship's structure as follows:

(a) The outer column is fully integrated with the (flexible mounted) deckhouse, *see* Fig. 13.1.3. In this case one or more pillars may need to be fitted underneath the outer column for additional vertical support. In cases that the deckhouse is flexible mounted on vibration mounts vibration mounts will also need to be fittted between the column and the additional pillar(s).

(b) The outer column is integrated in the (flexible mounted) deckhouse and is continued up to the bottom construction of the ship, *see* Fig. 13.1.4. In cases that the deckhouse is flexible mounted on vibration mounts the outer column will need to be mounted on vibration mounts in way of the bottom structure as well.

(c) The outer column is independent from the flexible mounted deckhouse and directly fitted onto the bottom construction of the ship, *see* Fig. 13.1.5. In this case the columns are fully integrated with the ship's structure and it may be desired to mount the wheelhouse on vibration mounts at the connection with the top of the innermost column in order to isolate it from vibrations generated within the ship.

1.1.4 In case of the elevating wheelhouse being arranged with columns (*see* Figs. 13.1.3 to 13.1.5), the bottom structure of the wheelhouse should consist of 4 main girders fitted in line with the inner column plating and forming a cross of a pair of beams. The ends of the girders in way of the wheelhouse external walls can be considered as 'free' whilst the girders can be considered as 'clamped' in way of the inner column plating. The primary bottom structure should therefore be considered as being built of 8 girders clamped at one side (at the inner column). *See* Fig. 13.1.6.

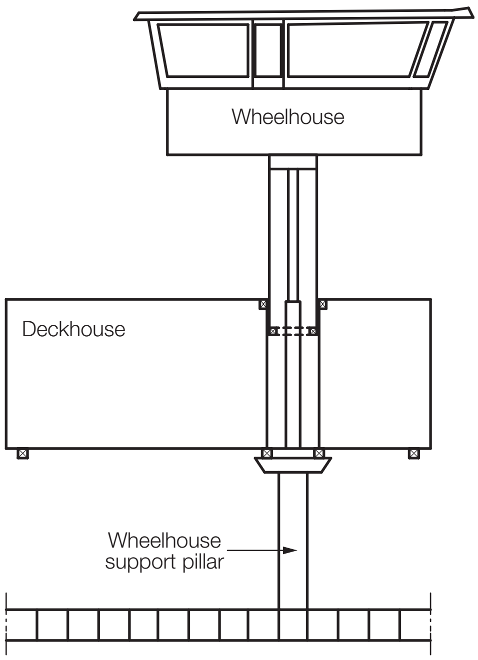


Fig. 13.1.3 Wheelhouse configuration 1

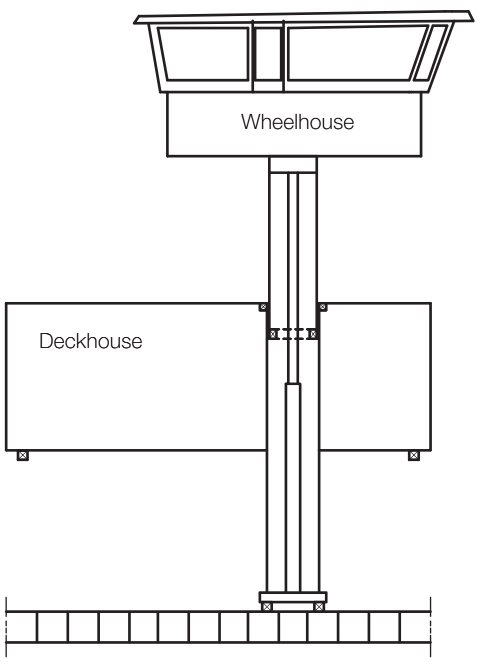


Fig. 13.1.4 Wheelhouse configuration 2

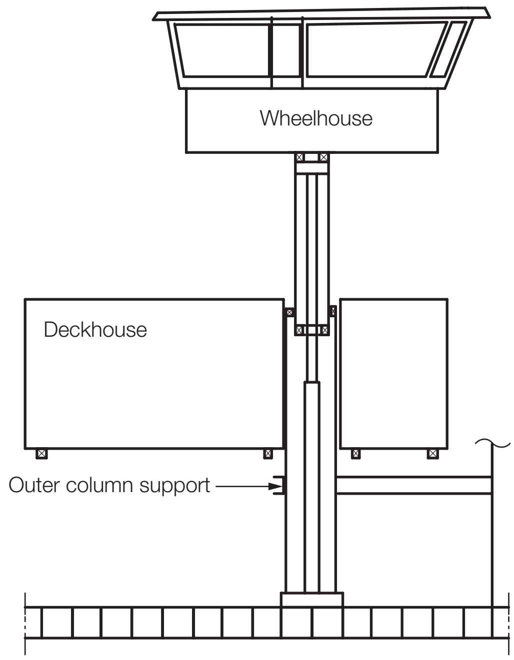


Fig. 13.1.5 Wheelhouse configuration 3

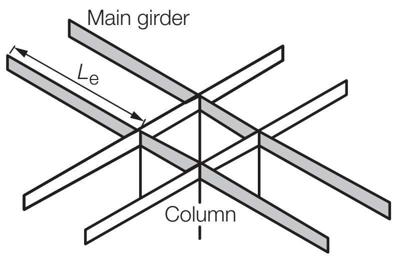


Fig. 13.1.6 Primary floor girders

1.2 General requirements

1.2.1 Elevating wheelhouse systems are to be made of steel or aluminium and are to be adequately supported. The materials used are to comply with the applicable requirements stated in the *Rules for the Manufacture, Testing and Certification of Materials.*

1.2.2 The wheelhouse is to be capable to support its own weight, including all equipment, and the maximum number of persons allowed in the wheelhouse simultaneously. A notice-plate in way of the entrance of the wheelhouse should be fitted stating the maximum number of persons allowed in the wheelhouse. The total mass corresponding with the number of people allowed should also be indicated. These figures are to be designated by the manufacturer. A minimum average weight of 75 kg per person is to be taken into account. Further specific design loads are given in Table 13.1.1 and Table 13.1.2.

Table 13.1.1 Design loads on columns and wheel house

Type of load	Condition	
	Normal (transverse heeling)	Collision on the bow
Wind	p_W = 0,150 tonf/m^2	p_W = 0,010 tonf/m^2
Heel	10° static	—
Accceleration	—	0,5 g

Table 13.1.2 Design loads on wheelhouse floor and roof

Item	Load (kN/m^2)
Floor	p_{floor} = 3,18
Gallery or walkway around wheelhouse	p_{walk} = 2,12
Roof	p_{roof} = 1,0

1.2.3 The columns are to be capable of withstanding loads induced by heeling or rolling of the ship as well as loads induced by a collision.

1.2.4 The blocks are to be capable of transferring the loads transferred by the columns.

1.2.5 The hydraulic cylinder(s) is/are to be capable of supporting the wheelhouse, the number of columns connected, and the specified number of persons in the wheelhouse, taking in account a dynamic factor of 1,20 on the static load.

1.2.6 The hydraulic cylinder(s) is/are to be of an approved type.

1.2.7 The cylinder support constructed in the bottom of the outer column is to be capable of withstanding the loads imposed by the hydraulic cylinder including its own weight and the dynamic factor mentioned in 1.2.5.

1.2.8 Attention is drawn to Pt 5, Ch 18 regarding machinery aspects and Pt 6, Ch 1 in respect of electrical and control engineering aspects.

1.2.9 When the proposed construction of the elevating wheelhouse system differs from the general design as detailed in 1.1.1, 1.1.3 and 1.1.4, it will be subject to special consideration.

1.2.10 The elevating wheelhouse system is only to be operated by the ship's crew after complete installation and appropriate instructions by the manufacturer and final acceptance by Lloyd's Register.

1.3 Design loads and column forces

1.3.1 The design loads on the columns, blocks and cylinder support, if applicable, are given in Table 13.1.1. The design loads given in Table 13.1.1 apply to ships navigating in Zone 3. For ships having the notation Zone 1 or Zone 2 in their Class Notation, the design loads are given in 1.7.

1.3.2 The design loads for the construction of the wheelhouse are given in Table 13.1.2 and are applicable to ships navigating in all zones.

1.3.3 The design bending moment and shear forces of the main girder at the clamping in way of the column is to be determined as outlined in Table 13.1.3. Actual bending moments, shear forces and stresses may also be determind by direct calculations taking account of actual lengths and relative stiffnesses of the girders.

Table 13.1.3 Determination of bending moment and shear force in main girder of wheelhouse foundation

Item	Parameter	Requirement
Maximum bending moment in main girder	*BM*	$\left(\frac{1}{6} q_1 + \frac{1}{3} q_2\right) b_2 + P\,a$ kN/m
Maximum shear force in main girder	*SF*	$\frac{1}{2}\left(q_1 + q_2\right) b + P$ kN
Symbols		

$q_1 = \dfrac{p_{floor}\, s_1}{1000}$ kN/m

$q_2 = \dfrac{p_{floor}\, s_2}{1000}$ kN/m

s_1 = spacing of main girder in way of clamping, in mm, *see also* Fig. 13.1.9
s_2 = spacing of main girder at end, in mm, *see also* Fig. 13.1.9
a = distance from inner column to wheelhouse side plating, in metres
b = distance from inner column to end of girder, in metres (= a in case of wheelhouse without gallery)

$P = \dfrac{p_{roof}\, Area_{roof}}{n}$ in kN

n = number of main girders (generally 8)
p_{roof} = as defined in Table 13.1.2, in kN/m^2
$Area_{roof}$ = area of roof, in m^2

NOTE
For clarification, *see also* Figs. 13.1.7, 13.1.8 and 13.1.9.

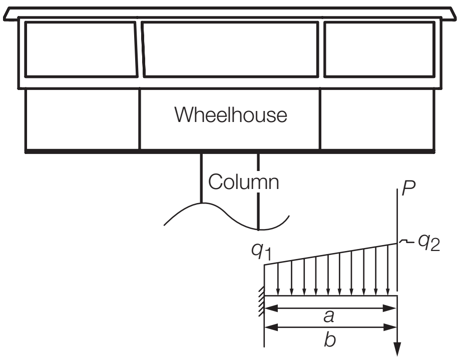


Fig. 13.1.7 Loadcase elevating wheelhouse

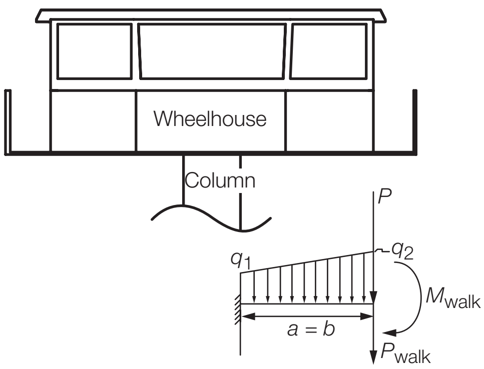


Fig. 13.1.8
Loadcase elevating wheelhouse with walkway

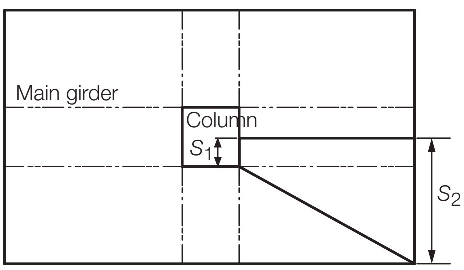


Fig. 13.1.9 Defenition S_1 and S_2

1.3.4 The column forces are the reaction forces resulting from the following:

- Loads due to the static heeling (Zone 3) or dynamic rolling (Zones 1 and 2) of the ship.
- Loads induced by a collision.
- Wind loads.

The method of calculation of these forces on the blocks is given in Table 13.1.4. Table 13.1.4 is based on the assumption that the longitudinal and transverse centre of gravity of the system is approximately at the centre of the columns. If this is not the case the effects are to be taken account of by further direct calculations.

Table 13.1.4 Block forces

Load	Requirement
Design bending moment, *M*	$\sum_{i}^{n} \left[A_i\, p_w\, h_{wi} + \left(\zeta\, m_i + F_{roll,dyn,i} \right) h_{mi} \right]$ tonfm
Design horizontal load, *F*	$\sum_{i}^{n} \left[A_i\, p_w + \zeta\, m_i + F_{roll,dyn,i} \right]$ tonfm
Upper block force R_{upper}, per block	$\frac{1}{2} \left(\frac{M}{overlap} + F \right)$ tonf
Lower block force R_{lower}, per block	$\frac{M}{2\ overlap}$ tonf
Symbols	
A_i =	projected area of part i of the elevating wheelhouse system, perpendicular to the wind direction, in m^2
h_{wi} =	distance of the centre of area A_i up to upper block, in metres
m_i =	mass of part i of the elevating wheelhouse system, in tonf
h_{mi} =	distance of the centre of gravity of part i of the elevating wheelhouse system up to upper block, in metres
$F_{roll,dyn,i}$ =	transverse component of dynamic roll, only applicable when sailing in Zone 1 or 2, *see* 1.7
n =	total number of parts of the elevating wheelhouse system, including the wheelhouse, excluding the column of the upper block under consideration and columns below, *see also* Note 1
p_w =	wind pressure, *see* Table 13.1.1
ζ =	sin *f* for heeled or rolling conditions; = 0,50 for collisions
f =	10° for Zone 3, 15° for Zone 2, 20° for Zone 1, *see also* 1.7
overlap =	distance between lower blocks of a column and the upper blocks of the column below when the wheelhouse is in the outmost lifted position, *see also* Note 2
NOTES 1. *See also* Figs. 13.1.10 to 13.1.12 for an example of n = 4 . 2. The required minimum overlap depends on the allowable forces. The following values could be used as a recommendation in the initial design stage: overlap ≈ 1 x maximum width of outer column for services in Zone 3, overlap ≈ 1,2 x maximum width of outer column for services in Zone 2, and overlap ≈ $1^1/2$ x maximum width of outer column for services in Zone 1 for the determination of the overlap between the outer column and the lowest middle column.	

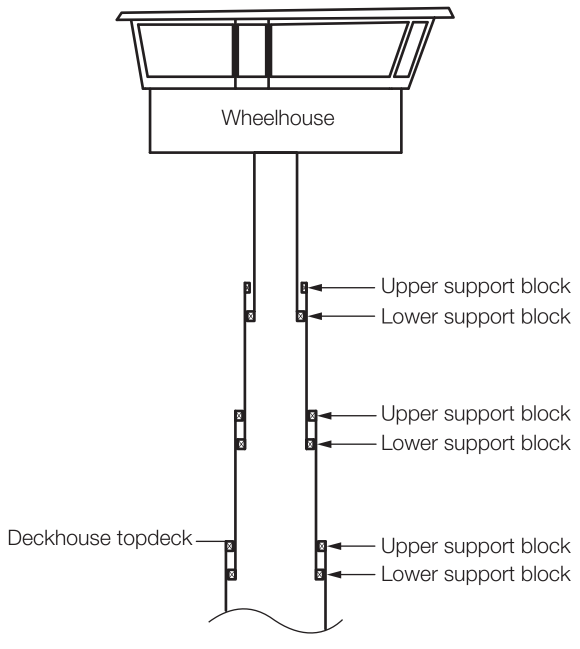


Fig. 13.1.10 Overview support/slidding blocks

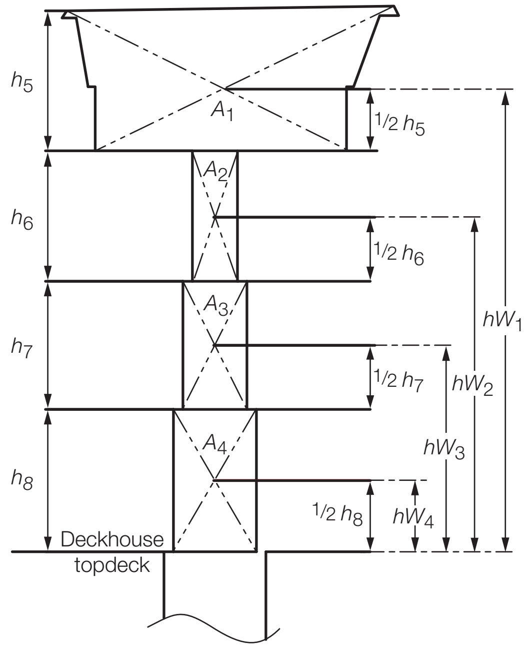


Fig. 13.1.12 Wind forces

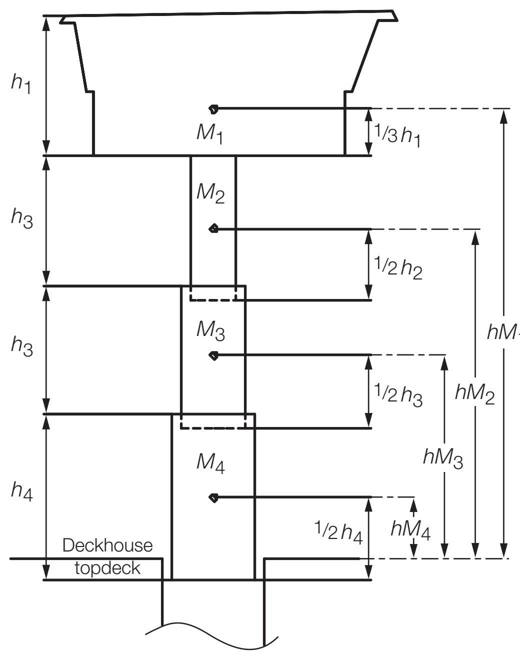


Fig. 13.1.11 Mass forces

1.4 Structural requirements

1.4.1 Where the outer column is integrated in the deckhouse (building methods in accordance with Fig. 13.1.3 and Fig. 13.1.4) the upper blocks of the outer column are to be in line with the topdeck of the deckhouse. Provisions are to be made for an efficient and adequate distribution of loads into this deck. A buckling analysis of the topdeck plating in way may be required. If necessary, anti-buckling strips are to be fitted. Preferrably, the side plating of the outer column is to be arranged in line with the beams and girders in the top and lower deck of the deckhouse. Where deck girders and beams are not in line, brackets are to be fitted in line with the column side plating connecting the outer column with the beams and girders in the deckhouse.

1.4.2 Where the outer column is independent from the flexible mounted deckhouse and directly fitted onto the single or double bottom construction of the ship, provisions are to be made to support the outer column at a distance as large as possible above the top of the bottom structure but not less than 2,0 m. These supports, consisting of heavy beams efficiently connected to the ship's supporting structure, are to be provided in the horizontal transverse and longitudinal direction of the ship in order to provide additional transverse and longitudinal support. In this way the occurrence of high bending moments induced by the outer column on the bottom structure are to be prevented.

1.4.3 The number, type and position of vibration mounts or so called flexibles are dependent on the type of mount, the weight of the elevating wheelhouse, the method of building in and the amount of weight of the deckhouse that is supported by the outer column. The vibration mounts should be of an approved type and should be installed in accordance with the manufacturer's recommendations.

1.4.4 If the cylinder support in the bottom of the outer column consists of an I-shaped beam, anti tripping brackets are to be placed on the beam in way of the cylinder. Tripping brackets are also to be placed on the beam in line with the vibration mounts below.

1.4.5 Items such as safety pins, axles, brackets, etc. are to be designed for the loads imposed on them including the appropriate dynamic factors using the allowable stresses as provided in Table 13.1.8.

1.5 Wheelhouse

1.5.1 In this Section, only requirements for the construction of the bottom structure of the wheelhouse are given. The construction of the side walls and roof is to be carried out in accordance with good shipbuilding practice in line with the Builder's procedures and standards.

1.5.2 The main girders are defined as primary members. Other beams and stiffeners are defined as secondary members.

1.5.3 The connection of the main girders to the inner column is to be such that these can be considered as clamped. Accordingly, the web of the main girder is to be in line with the plating of the inner column. (Double) continuous welding is required.

1.5.4 The effective plate width of the attached cover plating on the bottom side of the wheelhouse foundation is to be determined in accordance with Pt 3, Ch 3,3, with the factor *f* to be divided by 2. The effective width of a plate attached to the main girder is then calculated as follows:

$$b_{eff} = \frac{1}{2} f\,b$$

1.5.5 The number of holes in the main girders is to be kept to a minimum. Holes are not allowed in the main girder in way of the connection to the inner column. Generally, a minimum of 1,50 times the web depth of the main girder under consideration is required between the edge of a hole and the inner column.

1.5.6 Openings in beams are to have well rounded corners. The diameter or height of any opening should not exceed half the depth of the web of the beam. For rectangular openings, the length of the opening is limited to 65 per cent of the web height. The distance between openings should generally not exceed 75 per cent of the diameter or length of the opening.

1.5.7 Where larger holes are proposed, these are subject to special consideration and reinforcements by means of double plates or flanges having increased properties are required to compensate the loss of material.

1.5.8 The wheelhouse is to be capable of being closed gastight when installed on dry cargo ships carrying dangerous goods in large quantities or on tankers carrying dangerous goods. *See* Pt 4, Ch 1,12 and Pt 4, Ch 4 respectively.

1.5.9 In case of a gallery or walkway partly or totally being fitted around the wheelhouse, extra attention is to be paid to its supporting arrangement. It is to be ensured that the beams are in line with local beams or main girders fitted in the wheelhouse and are well clamped without the presence of any hard spots.

1.5.10 The stresses in the main girders of the wheelhouse foundation can be calculated as stated in Table 13.1.5.

1.5.11 The stresses in the other beams can be calculated as stated in Table 13.1.6.

1.5.12 The stresses as calculated in Table 13.1.5 and Table 13.1.6 are to be lower than the allowable stresses as given in 1.8.

Table 13.1.5 Stresses in main girders of wheelhouse

Item	Parameter	Requirement
Bending stress	σ_b	$\frac{BM}{Z}$ 1000 N/mm2
Shear stress	τ	$\frac{SF}{A_w}$ 1000 N/mm2
Symbols		
BM = max bending moment acc. to Table 13.1.3 SF = max shear force acc. to Table 13.1.3 Z = section modulus of main girder under consideration, in cm^3 A_w = web area of main girder under consideration, in mm^2		

Table 13.1.6 Stresses in secondary members of wheelhouse

Item	Parameter	Requirement
Bending stress	σ_{bl}	$\phi_Z \frac{p\,s\,l^2}{Z}$ 1000 N/mm^2
Shear stress	τ_1	$\phi_A \frac{p\,s\,l}{A_w}$ 1000 N/mm^2
Symbols		
ϕ_Z = section modulus coefficient, to be taken as 0,1 for secondary members where the end fixity of both ends are considered to be partial; to be taken as 0,5 for cantilever beams (as for the beam in the gallery) ϕ_A = web area coefficient, to be taken as 0,5 for secondary members where the end fixity of both ends are considered to be partial; to be taken as 1 for cantilever beams (as for the beam in the gallery) p = p_{floor} or p_{walk} as applicable as defined in Table 13.1.2 s = stiffener spacing, in mm l = length of stiffener, in metres Z = section modulus of stiffener, in cm^3 A_w = web area of stiffener, in mm^2		

1.6 Columns

1.6.1 The thickness of the column plating is to be determined for each column. Parameters are the reaction forces in the blocks and the design bending moment in the colums. The thickness of the plating of the outer column is to be equal to the thickness of the lowest middle column (or inner column in case of the total number of columns is 2). The minimum thickness, t_p is to be taken as the greater of t_{p1} and t_{p2}:

$$t_{p1} = \sqrt[3]{\frac{5964\ fos\ f_{block}\ b_{c1}}{E}}\ \text{mm}$$

$$t_{p2} = \frac{9{,}81M}{sf\ b_{c1}\ b_{c2}\ \sigma_0} \times 10^6\ \text{mm}$$

where

t_p = plating thickness of column under consideration, in mm, to be ≥ 8 mm for steel plating and ≥ $\sqrt{k}$ 8 mm for aluminium alloys

k = material factor = $\frac{235}{\sigma_0}$

σ_0 = yield stress of the used plating material or the 0,2 per cent proof stress (in the welded condition), in N/mm^2

fos = factor of safety with respect to buckling aspects; to be taken as 1,2 for normal (rolling) conditions and 1,0 for collision condition

F_{block} = reaction force in upper block of the column below, in tonf, = R_{upper} as calculated in accordance with Table 13.1.4 and, if applicable, Table 13.1.7, either in transverse or longitudinal direction

E = modulus of elasticity of material, in N/mm^2

b_{c1} = breadth of column under consideration, in mm, measured in the direction of F_{block}

b_{c2} = breadth of column under consideration, in mm, measured perpendicular to the direction of F_{block}

M = design bending moment, in tonfm, as calculated in accordance. with Table 13.1.4 and, if applicable, Table 13.1.7

sf = safety factor for axial stresses, *see* Table 13.1.8.

1.6.2 Where the proposed thickness is not in accordance to the required thickness, a double plate may be fitted in line with the blocks to assure sufficient strength against buckling. The double plate should be such that the least moment of inertia of the two plates together, I_{comb}, has a minimum value of:

$$I_{comb} \geq \frac{fos\ 497\ b^2_{c1}\ F_{block}}{E}\ \text{mm}^4$$

taking into account an effective breadth of the column plating itself equal to the value of b_{c1}.

1.6.3 Generally, when a double plate is proposed, the dimensions b x t are to be as follows:

	proposed column dimensions	proposed column dimensions
breadth	b_c	$b = 0{,}3 \times b_c$
thickness	t_p	$t = t_p$

Table 13.1.7 Determination of transverse forces of each individual component of the elevating wheelhouse system in Zones 1 and 2

Item	Requirement
Wind pressure, p_w	0,038 tonf/m^2
Roll period, T_r	$0{,}7\ \frac{8}{\sqrt{GM}}$, s to be taken as 6 if *GM* is unknown
Transverse component of static roll, $F_{roll,\ static,\ i}$, of the part i of the elevating wheelhouse system, *see also* Note 1	$\zeta\ m_i$, tonf
Transverse component of dynamic roll, $F_{roll,\ dyn,\ i}$, of the part i of the elevating wheelhouse system, *see also* Note 2	$0{,}07024\ m_i\ \frac{\varphi}{T_r^2}\ z_i$, tonf

Symbols

m_i = mass of the part i of the elevating wheelhouse system, in tonf

z_i = distance (perpendicular to deck) of centre of gravity of the part i to ship's centre of gravity, metres

ζ = sin(f)

f = max roll angle of the ship, in degrees, to be taken as:
For Zone 1 service: 20° if the actual heeling angle is unknown
For Zone 2 service: 15° if the actual heeling angle is unknown

B = breadth of ship, in metres

GM = metacentre height of ship, in metres

NOTES
1. The $F_{roll,\ static,\ i}$ is the mass component in the determination of F and M in Table 13.1.4.
2. The $F_{roll,\ dyn,\ i}$ is the dynamic component in the determination of F and M in Table 13.1.4.
3. Due to the different ship's sailing conditions, the rolling conditions may differ for each individual sailing condition. Therefore the transverse forces on the columns are at least to be calculated for the two main sailing conditions, i.e. the full load condition and the ballast condition.
4. Zones 1, 2, and 3 are defined in Pt 1, Ch 2,2.1.

1.6.4 In view of potentionally high block forces the strength and means of attachment of the column plating in way of the blocks is to be specially considered and details of the blocks and plating in way are to be submitted for consideration.

1.7 Service in Zones 1 and 2

1.7.1 Elevating wheelhouses on ships intended to navigate in Zones 1 or 2 are to withstand both the normal loads, as calculated in accordance with Table 13.1.4, as well as the forces induced by rolling of the ship when sailing under increased conditions as for Zones 1 and 2. In this case the additional loads are to be calculated in accordance with Table 13.1.7. The formulas in Table 13.1.7 should be applied to each individual component of the elevating wheelhouse system. The total bending moment acting on the outer column and the resulting reaction forces of the blocks are to be calculated as outlined in Table 13.1.4. The allowable stresses are to be determined according to 1.8.

1.7.2 The Builder of the elevating wheelhouse system is to be provided with proper values of the hydrodynamic and hydrostatic parameters *B*, *GM*, and *f*.

1.7.3 When T_r and f are known through ship measurements or detailed analysis, these values are to be used in the calculation of Table 13.1.7.

1.8 Allowable stresses

1.8.1 The safety factors listed in Table 13.1.8 are the limiting stress coefficients to be multiplied with the yield stress or the 0,2 per cent proof stress of the material as applicable. Thus the allowable stress = safety factor x σ_o, with σ_o as defined in 1.6.

1.8.2 In the determination of the magnitude of the equivalent stress, σ_{eq}, it is assumed that the stresses are combined using the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x^2 + 3\,\tau^2}$$

1.9 Welding requirements

1.9.1 (Double) continuous welding is to be adopted in the following locations and may be used elsewhere if desired:

(a) Primary and secondary members to plating in way of end connections.
(b) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets.
(c) The cylinder supporting structure in the bottom of the outer column to the column plating.
(d) The connection of the main girders of the wheelhouse foundation to the side plating of the inner column.
(e) Double plate on middle column if needed to fulfill buckling requirements.
(f) Double plate on cylinder support if needed to fulfill shear strength requirements.
(g) Anti-tripping brackets where high local loadings are imposed.

1.9.2 The throat thickness of the (double) continuous welds is to be 0,44 x t_p, with t_p being the least value of the plating thicknesses being joined. Full or deep penetration welding may be required where high local loadings are imposed.

Table 13.1.8 Safety factors on yield or 0,2 per cent proof stress

Type of stress	Condition		
General construction	Inland waterways – Normal condition (Zone 3)	Zone 1 and Zone 2	Collision
Bending + normal, σ_x	0,60	0,75	0,90
Shear, τ	0,42	0,53	0,64
Equivalent, σ_{eq}	0,75	0,85	1,0
Local stresses on safety pins, axles, brackets, etc.			
Axial	0,50	0,63	0,75
Shear	0,35	0,44	0,53
Equivalent	0,63	0,71	0,83

NOTE
The bending and normal stresses are known as axial stresses.

1.10 Non structurally related items

1.10.1 The recommendations listed in this paragraph are non-Classification items and may be overruled or waived by different or additional requirements from the applicable National Authorities. It is however strongly recommended to implement these recommendations.

1.10.2 It is recommended to clearly designate and mark the area directly below the wheelhouse as an area of non trespassing.

1.10.3 When the non trespass area as defined in 1.10.2 should be trespassed for maintenance purposes or for other reasons, it is recommended that the elevating wheelhouse is secured from moving up or down.

1.10.4 External stairs for access to the wheelhouse are not a classification item. It is however strongly recommended clearly indicate the number of persons that are allowed simultaneously on the stairs and for which the stairs have been approved by the relevant authority.

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RULES AND REGULATIONS FOR THE CLASSIFICATION OF INLAND WATERWAYS SHIPS

SHIP STRUCTURES (SHIP TYPES)

NOVEMBER 2008

PART 4

Lloyd's Register

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Part 4

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to self-propelled ships with machinery aft and non-propelled ships (barges) towed and/or pushed or carried alongside another ship, designed primarily for the carriage of:
(a) general dry cargo; or
(b) containers; or
(c) bulk heavy dry cargoes (including ore) in holds;
(d) either type (a) or (b) and (c) type cargoes.

1.1.2 The structural requirements of this Chapter are intended to cover the midship region as defined in Pt 3, Ch 3,2.2 for ships having a length not exceeding 135 m, a ratio of length to depth generally not exceeding 35 and a ratio of breadth to depth not exceeding 5.

1.1.3 Arrangements and scantlings forward and aft of the midship region are to comply with Pt 3, Ch 5 and Ch 6 so far as applicable; the remaining requirements of Part 3 are also to be complied with as appropriate to the intended arrangements.

1.1.4 For ships intended to carry dangerous goods in higher quantities as listed in Part 7 of the ADNR/ADN, *see* Section 12. This Section also provides general guidance on the applicability and contents of the ADNR/ADN.

1.2 Structural configuration

1.2.1 This Chapter provides for a basic structural configuration of a single deck hull with wide hatch openings and continuous hatch side coamings, a single or double skin arrangement in way of the cargo space and a single or double bottom arrangement. Consideration will be given to other arrangements.

1.2.2 Longitudinal or transverse framing may be adopted. Ships with a ratio of length to depth exceeding 25 or a length, *L*, over 70 m and having a double bottom, are generally to be constructed with longitudinal framing in the bottom. Alternatively, transverse framing may be adopted, provided suitable longitudinal stiffening is fitted to the bottom plating. If no double bottom is fitted, transverse framing with suitable longitudinal stiffening is, in general, to be applied.

1.2.3 The number and disposition of transverse bulkheads are to be as required by Pt 3, Ch 7. Additional bulkheads may have to be fitted to provide for sufficient transverse strength of the vessel.

1.3 Class notation

1.3.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2,2.

1.3.2 Ships intended for the carriage of general cargoes in holds and on deck, with a loading equivalent to a stowage rate greater than 1,39 m^3/tonne, corresponding to a specific weight of cargo less than 0,72 tonne/m^3 and complying with the requirements of this Chapter will be eligible to be classed:
A1 I.W.W. Cargo Ship
or
A1 I.W.W. Cargo Barge.

1.3.3 Ships intended for the carriage of general cargoes in holds and on deck, with a loading equivalent to a stowage rate greater than 1,39 m^3/tonne, corresponding to a specific weight of cargo less than 0,72 tonne/m^3 and intended to carry containers and complying with the requirements of this Chapter will be eligible to be classed:
A1 I.W.W. Container Ship
or
A1 I.W.W. Container Barge.

1.3.4 Ships designed primarily for the carriage of bulk heavy dry cargoes (including ore) in holds, with a maximum specified stowage rate of 1,39 m^3/tonne, corresponding to a minimum specific weight of cargo 0,72 tonne/m^3 and complying with the requirements of this Chapter will be eligible to be classed:
A1 I.W.W. Bulk Carrier
or
A1 I.W.W. Bulk Carrier Barge.

1.3.5 Double-hull ships built in compliance with Chapter 9, Section 9.1.0.80 of the ADNR/ADN and complying with the additional requirements of Section 12 of this Chapter will be eligible to be classed:
DG
where DG stands for Dangerous Goods.

1.3.6 Where applicable, combinations of the above class notations may be assigned, i.e.:

A1 I.W.W. DG Container Ship/Bulk Carrier.

1.3.7 The Regulations for classification and assignment of class notations are given in Pt 1, Ch 2, to which reference should be made on the survey request form.

1.3.8 Where a ship has been specially designed, modified and/or arranged in accordance with the additional requirements for Zones 1 or 2, for service extension, for any special loading or discharging sequence or for navigation in ice, the appropriate class notation will be assigned.

1.4 Information required

1.4.1 For the information required, *see* Pt 3, Ch 1,5. In addition, the following are to be supplied:

(a) The draught desired in conjunction with the contemplated loading sequence, *see also* 2.1.1.
(b) Cargo loading on inner bottom and if applicable, also on hatchways and deck, *see* 1.3 and Pt 3, Ch 3,4.
(c) Container stack weights, *see* 9.1.2.
(d) The maximum pressure head in service on tanks. Where tanks are interconnected with side tanks, this is to be clearly specified.
(e) Details of tanks which will be solely used for water ballast in the light condition and which will be empty in the loaded condition.

1.5 Symbols and definitions

1.5.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D, T and C_b are as defined in Pt 3, Ch 1,6.1

l = overall length of stiffening member, in metres, *see* Pt 3, Ch 3,3.2

l_e = effective length of stiffening member, in metres, *see* Pt 3, Ch 3,3.3

s = spacing of secondary stiffeners, i.e. frames, beams or stiffeners, in metres

t = thickness of plating, in mm

I = inertia of stiffening member, in cm^4, *see* Pt 3, Ch 3,3.2

S = spacing or mean spacing, of primary members, i.e. girders, transverses, webs, etc., in metres

Z = section modulus of stiffening member, in cm^3, *see* Pt 3, Ch 3,3.2.

■ *Section 2*
Materials and protection

2.1 Materials and grades of steel

2.1.1 Materials and grades of steel are to comply with the requirements of Pt 3, Ch 2,1.

2.1.2 Grades of steel used in the construction of continuous coamings are to comply with Table 1.2.1.

Table 1.2.1 Grades of steel of continuous coamings

Thickness, t, in mm	Mild steel	H.T. steel
$t \leq 20$	A	AH
$t > 20$	D	DH

2.2 Protection of steelwork

2.2.1 For the protection of steelwork, the requirements of Pt 3, Ch 2,2 and Ch 2,3 are to be complied with.

■ *Section 3*
Longitudinal strength

3.1 General

3.1.1 The longitudinal strength of a dry cargo ship is to comply with the requirements of Pt 3, Chapter 4 for the longitudinal strength Category contemplated.

■ *Section 4*
Deck plating and continuous longitudinal hatch side coamings

4.1 General

4.1.1 The requirements of this Section cover the topside structure which includes the following structural parts of the ship:

- deck plating and continuous longitudinal hatch coamings.

4.1.2 For ships over 40 m in length, the thickness of the deck and coaming plating may require to be increased to obtain the midship section modulus required in Pt 3, Ch 4.

4.2 Deck plating

4.2.1 The thickness of the deck plating is to comply with Table 1.4.1, and is generally to be maintained one frame space fore and aft of the hatch opening. The plating thickness may however be reduced beyond 0,5L amidships in accordance with the requirements for taper given in Pt 3, Ch 3,2.5. As an alternative, direct calculations may also be used to prove that the allowable stresses given in Section 13 will not be exceeded. The thickness at the end of the hatch opening should however be not less than 80 per cent of the thickness amidships nor less than the minimum thickness required by Table 1.4.1.

4.2.2 Openings in the deck should be kept to a minimum and are to be arranged clear of the hatch corners; compensation for these openings will generally be required.

Table 1.4.1 Topside structure (general)

Item and parameter	Requirements for all ships
(1) Deck thickness	The greater of: $t = (5{,}6 + 0{,}039L)\sqrt{s}$ mm $t = 10s$ mm
(2) Hatch coaming minimum thickness	The greater of: $t = 0{,}042\ (L_1 + 200)\ d_c$ mm $t = (6 + 0{,}06L)\ \sqrt{d_c}$ mm
(3) Upper hatch coaming stiffener inertia	$I_s = S^2 A_{st}$ cm^4
Symbols	
L, D and s are as defined in 1.5.1 d_c = vertical distance, in metres, between deck and horizontal stiffener on coaming or between horizontal stiffeners A_{st} = area of stiffener including attached plating, in cm^2 S = distance between coaming stiffeners, in metres L_1 = L but to be taken not less than 40 m I_s = upper hatch coaming stiffener inertia	
NOTE The scantlings of the topside structural parts may require to be increased to satisfy the hull girder bending stresses and buckling criteria in Pt 3, Ch 4.	

4.3 Continuous longitudinal hatch coamings

4.3.1 The thickness of the coaming is to comply with the requirements of Table 1.4.1 and is to be maintained over the length of the hatch opening. The plating thickness may, however, be reduced beyond 0,5*L* amidships in accordance with the requirements for taper given in Pt 3, Ch 3,2.5. Where coaming terminates at the end(s) of the hold, the combined taper area of the topside comprising coaming, deck and sheerstrake is to be used. As an alternative, direct calculations may also be used to prove that the allowable stresses given in Section 13 will not be exceeded. The thickness at the end of the hatch opening should, however, be not less than 80 per cent of the thickness amidships nor less than the minimum thickness required by Table 1.4.1.

4.3.2 The height of the hatch coaming is, in general, to be not more than 1,60 m above the deck and the hatch coaming is to extend at least 250 mm below the deck plating to provide for an efficient connection of the frame brackets and is to be substantially stiffened at the lower edge.

4.3.3 Coamings are to be stiffened at their upper edge by a substantial horizontal stiffener having scantlings complying with Table 1.4.1. The distance between the upper edge of the coaming and this stiffener is, generally, not to exceed 10 times the coaming thickness in way. If the height of the coaming is more than 1,0 m above deck, it is recommended to fit an additional horizontal stiffener halfway between the upper horizontal stiffener and the deck. Proposals to omit the longitudinal stiffener(s) are to be supported by additional buckling calculations.

4.3.4 Cut-outs in the upper edge of the coaming to accommodate hatchcovers are to be carefully designed and cut, with small rounded corners and be ground smooth after cutting. Hull girder bending stresses are to be calculated at the level of the lower edge of the cut-out.

4.3.5 Hatch coaming stays are to be fitted not more than 3 m apart. On ships regularly discharged by grabs, the distance between the stays is not to exceed 2 m.

■ *Section 5* Hull envelope plating

5.1 General

5.1.1 This Section covers the requirements for the shell envelope plating, *viz*., keel, bottom, bilge and side shell plating. For deck plating, *see* Section 4. The thickness of shell envelope plating amidships is to be not less than required in Table 1.5.1, but for ships over 40 m in length, the thickness of the bottom plating may require to be increased to obtain the midship section modulus required in Pt 3, Ch 4.

5.1.2 For requirements in respect of structural details, *see* Pt 3, Ch 10.

5.2 Keel

5.2.1 The thickness and breadth of the keel plate is to comply with the requirements of Table 1.5.1, and is to be maintained over the full length of the ship.

5.2.2 The scantlings of a bar keel, if fitted, are to comply with the requirements of Table 1.5.1.

5.3 Shell plating

5.3.1 The thickness of bottom shell and side shell plating is to be maintained over 0,5*L* amidships. Thicknesses are to comply with Table 1.5.1 and may be tapered to the end thickness in the fore end and aft end of the ship, *see* Pt 3, Ch 5, according to the requirements for taper given in Pt 3, Ch 3,2.5. Where the bottom is transversely framed, the bottom is, in general, to be reinforced with additional longitudinal stiffeners.

5.3.2 When local doublers are used on the side shell plating to act as rubbing bars, full penetration welding of the is to be ensured and suitable backing bars or copper shims are to be used for welding the butt welds to prevent actual attachment to the shell plating in way. The doublers are to be attached to the sideshell plating with seam welding only after individual welding of the butt welds as described above. Doublers are not to be used in lieu of an inserted sheerstrake as required by 5.5. Doublers are not to be included in the calculation of the hull section modulus.

Table 1.5.1 Shell envelope plating

Item and parameter	Requirement
(1) Plate keel breadth Thickness	$0{,}1B$ but not less than 0,75 m As bottom plating t_b When there is a rise of floor, the thickness is to be increased by 1 mm
(2) Bar keel thickness Height	$t = 0{,}37L + 10$ mm $d_k = 0{,}7L + 75$ mm
(3) Bottom plating thickness	The greater of: $t_b = (5{,}6 + 0{,}054L)\sqrt{s}$ $t_b = 10s$, *see also* Note
(4) Bilge plating thickness	$t = t_b + 2$ mm
(5) Bilge chine bars (a) Round bars diameter (b) Square bars side (c) Anglebars flange thickness	 $3t_b$ mm, but not less than 30 mm $3t_b$ mm, but not less than 30 mm $t = 2t_b$ mm
(6) Side shell plating Thickness	The greater of: $t = (5{,}6 + 0{,}054L)\sqrt{s}$ $t = 10s$
(7) Minimum width sheerstrake	$W_{sh} = 0{,}08D$ m but not less than 0,20 m
(8) Sheerstrake thickness	t = side shell thickness + 5 mm
(9) Doublers clear of sheerstrake (when fitted) Width Thickness	 W_d = between 0,10 and 0,45 m The greater of $t = 30W_d$ t = required thickness for the side shell plating
Symbols	
L, B, D, s and t are as defined in 1.5.1 d_k = height of bar keel t_b = thickness of bottom plating, in mm	
NOTE The thickness of the bottom plating is also to satisfy the buckling requirements and hull girder stress criteria in Pt 3, Ch 4.	

5.4 Bilge plating

5.4.1 The thickness of the bilge plating is to be maintained from amidships to well beyond the forward and aft shoulder of the bilge, but at least over the midship region. For definition of shoulders, *see* Pt 3, Ch 5,2.4.2.

5.4.2 The bilge radius is to be at least 10 times the thickness of the bilge plating and the bilge strake is to extend at least 100 mm on either side of the radius of the bilge plate.

5.4.3 Square bilges, constructed by solid round, square or externally fitted angle bars, *see* Fig. 1.5.1, are to comply with Table 1.5.1. The bottom plating and the side shell plating, adjacent to the round, square or angle bars need not be increased in thickness above that of the bottom plating or side shell plating in way.

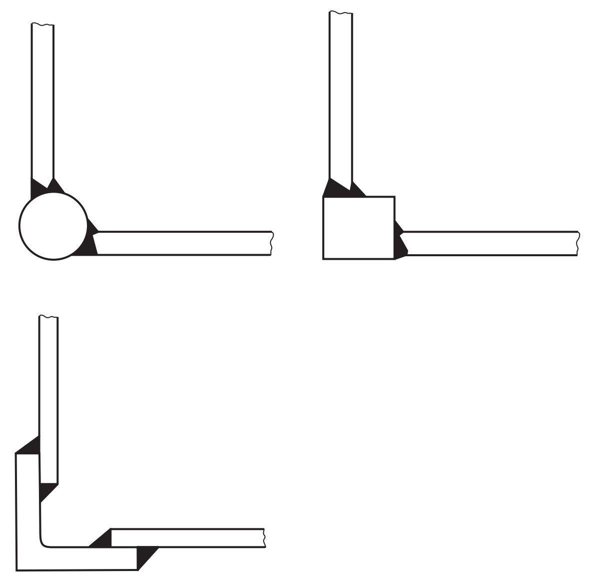


Fig. 1.5.1 Square bilge arrangements

5.5 Sheerstrake

5.5.1 The width and thickness of the sheerstrake is to comply with Table 1.5.1, and is to be maintained over the length of the hatch opening, including one frame space forward and aft of the hatch opening, but at least over 0,5L amidships.

5.6 Shell openings

5.6.1 Openings in the shell plating are to have well-rounded corners; compensation is generally only required for openings having a width greater than 250 mm. Openings in way of or near to the bilge radius fitted in the midship region are to be circular or elliptical.

■ *Section 6* Single bottom structure

6.1 General

6.1.1 Requirements are given in this Section for transversely framed single bottoms. The scantlings of girders and floors are to be not less than required in Table 1.6.1.

Table 1.6.1 Transversely framed single bottoms

Item	Parameter	Requirements
(1) Centreline girder	Web and face plate thickness Width of face plate	t = $0{,}008 d_w + 3$ mm, *see* Note b_f = 140s mm
(2) Side keelson bars	Cross-sectional area	A_k = $8 + 0{,}6B$ cm^2
(3) Floors	Web depth at centreline Web thickness Face plate thickness Ratio of unsupported faceplate width and faceplate thickness Minimum required modulus Inertia	d_w = 40B mm t_w = $0{,}008 d_w + 3$ mm, *see* Note $t \geq t_w$ mm max 15 $Z = 6T\,s\,B^2$ cm^3 $I = 2{,}2 \times ZI$ cm^4
Symbols		
Z, B, T, s and t are as defined in 1.5.1 b_f = width of face plate of floor or girder, in mm d_w = web depth of floor or girder, in mm t_w = thickness of floor web plate, in mm A_k = cross-sectional area of keelson bar, in cm^2		
NOTE In ships regularly discharged by grabs the thickness of floors and girders is to be not less than 8 mm.		

6.1.2 It is recommended that the bottom of ships intended to regularly rest aground be additionally strengthened in order to withstand the increased loads to which they may be subjected. Scallops or openings (unless reinforced) are not permitted.

6.1.3 In general, single bottom structures are only to be used in general dry cargo ships designed for a stowage rate greater than 1,39 m^3/tonne, corresponding to a specific weight of cargo less than 0,72 tonne/m^3. For stowage rates less than 1,39 m^3/tonne, the scantlings will be specially considered.

6.2 Girders

6.2.1 A centreline girder is to be fitted and is to have the same depth as the floors at centreline. If the breadth of the ship exceeds 7 m, side keelson bars are to be fitted on top of floors spaced not more than 3 m apart. The keelson bars are to be channel bars or other bars with sufficient rigidity.

6.3 Floors

6.3.1 Plate floors are to be fitted at every frame. The top of floors may be level from side to side, but in ships having considerable rise of floor, the depth of the floor plates is to be suitably increased. The floors may be cut at the centreline, with the centre girder web plate continuous, provided the transverse strength of the floors is maintained. The upper edge of the floors is to be suitably stiffened. Floors which are subjected to concentrated loads will be specially considered.

6.3.2 Floors are to be provided with drain holes, sufficient in number and size, to allow water to flow to the pump suctions.

6.4 Ceiling

6.4.1 Close ceiling is to be laid on floors and/or girders of single bottom arrangements, on inner bottom plating of double bottoms and over bilges if fitted, and is to be readily removable. The spaces between the frames at the top of bilge ceiling are to be closed by steel plates or other suitable means such as wooden chocks, cement, etc. Inner bottom manhole covers or fittings, if projecting above the inner bottom plating, are to be properly protected.

6.4.2 The thickness of ceiling is given in Table 1.6.2.

Table 1.6.2 Ceilings

Single bottom ceiling	Thickness	
	Soft wood	Hard wood
Frame spacing maximum 0,5 m, *see* Note	50 mm	38 mm
Ships regularly discharged by grabs	—	50 mm
NOTE If the frame spacing is in excess of 0,5 m the thickness of the ceiling is to be: $\dfrac{\text{Actual frame spacing in m} \times \text{table thickness}}{0{,}5}$		

6.4.3 Where the frames are inclined forward and aft in the holds, it is recommended that cargo battens be arranged in these areas.

Section 7 Double bottom structure

7.1 General

7.1.1 Requirements are given in this Section for a double-bottom construction with a transverse or a longitudinal framing system. The scantlings of girders, floors, inner bottom plating and longitudinals are to be not less than required in Table 1.7.1. *See also* Sections 8 and 9 for additional requirements for bottom structures in Bulk Carriers and Container ships.

Table 1.7.1 Double-bottom structure

Item	Parameter	Requirement
(1) Double bottom at centreline	Minimum depth	d_f = 35B mm
(2) Centre girder and side girder	Thickness	The greater of: t = 0,008d_f + 3,0 mm t = 8,0 mm
(3) Floors in a transverse framing system	Thickness Modulus	The greater of: t = 0,0085d_f + 2,0 mm t = 7,0 mm $Z = CTsl_b^2$
(4) Floors in a longitudinal framing system	Thickness Modulus	The greater of: t = 0,009d_f + 2,0 mm t = 8,0 mm $Z = CTsl_b^2$
(5) Watertight floors	Thickness	The greater of: t = 0,0085d_f + 3,0 mm t = 8,0 mm
(6) Inner bottom plating	Thickness	The greater of: t = 12s mm t = 6,0 mm
(7) Inner bottom longitudinals	Modulus	$Z = 4{,}85 H_c\, s\, l_e^2$ cm^3
(8) Bottom longitudinals	Modulus	$Z = (3{,}95 + 0{,}04 L_1) D_1\, s\, l_e^2$ cm^3

Symbols

L, B, D, T, S, s, t *and* Z are as defined in 1.5.1

- l_b = the width of the double bottom, in metres, and is normally the breadth of the ship. If longitudinal bulkheads or equivalent supports are provided, an equivalent breadth may be used, but this is to be taken as not less than 0,8B
- l_e = effective length of stiffening members, in metres, as defined in Pt 3, Ch 3,3.3, but is to be taken not less than 1,5 m
- t_i = thickness of inner bottom plating or bottom plating, whichever is the lesser, in mm
- A_s = minimum web sectional area at ends of floors (at toes of frames), in cm^2
- D_1 = D, but need not be taken greater than T + 0,4 m
- H_c = height from inner bottom to underside of deck or to the top of hatch coaming, in metres, as defined in Pt 3, Ch 3,4.2.1
- L_1 = L but is to be taken not less than 65 m, nor greater than 110 m
- C = 6 for general dry cargo ships and container ships
- C = 7 for bulk carriers

7.1.2 The depth of the double-bottom is to comply with the requirements of Table 1.7.1, but it is recommended that the double bottom space be accessible for inspection and surveys, *see* Pt 1, Ch 3,4.2.6.

7.1.3 Provision is to be made for free passage of air and water from all parts of the double-bottom compartments to the air pipes and suctions, account being taken of the pumping rates required. Where access openings are cut in the floors and girders, the size of openings should not, in general, exceed 50 per cent of the double-bottom depth. Openings are to be avoided in way of ends of floors and girders, and in way of concentrated loads.

7.2 Girders

7.2.1 A centreline girder is generally required in ships with a breadth, B, of more than 6 m. A side girder is to be fitted on each side of the centreline in ships with a breadth, B, of more than 12 m and transversely framed bottom construction. Proposals to omit the centreline girder and/or side girders will be specially considered, but adequate support must be provided on the centreline for docking purposes.

7.3 Floors

7.3.1 In transversely framed double bottoms, floors are to be fitted at every frame.

7.3.2 In longitudinally framed double bottoms, floors are to be fitted at a spacing not exceeding 2,5 m. Vertical stiffeners having a depth not less than 50 mm are to be fitted to the floors at every fourth longitudinal. In between the floors, brackets are to be fitted in the double bottom in line with the transverse side frames, connected to tank top and shell plating and extending to the nearest bottom and inner bottom longitudinal. Midway between floors, brackets are to be fitted on either side of the centreline, extending to the nearest bottom and inner bottom longitudinals. The free edges of the brackets are to be suitably stiffened.

7.3.3 Plate floors are also to be arranged under bulkheads, and in line with web frames fitted in the side structure. Floors subjected to concentrated loads will be specially considered.

7.4 Inner bottom plating

7.4.1 The thickness of the inner bottom plating is to comply with the requirements of Table 1.7.1. Where no ceiling is laid on the inner bottom plating, the thickness of the plating is to be increased by 2 mm. The inner bottom plating may be attached by slot fillet welds to the facebars or flanges of the floors.

7.5 Longitudinals

7.5.1 The scantlings of bottom longitudinals and inner bottom longitudinals are to comply with the requirements of Table 1.7.1 and are based on end connections in accordance with Pt 3, Ch 10,3.

■ *Section 8* Additional requirements for double bottom structures in bulk carriers

8.1 General

8.1.1 The requirements of Section 7 are to be applied together with the requirements of Table 1.8.1 in this Section.

Table 1.8.1 Requirements for double-bottom structures in bulk carriers

Item	Parameter	Requirement
(1) Inner bottom plating	Thickness	The greater of: $t = 4s\sqrt{P_0}$ mm $t = 8$ mm This thickness is to be increased by 4 mm when no ceiling is fitted
(2) Girders and floors	Thickness	Not less than 8 mm
(3) Inner bottom longitudinals	Section modulus	(1) Within 0,25*B* on either side of centreline: $ZI = 7{,}25 P_0 s\, l_e^2$ cm^3 (2) Outside 0,25*B* from centreline: The greater of: (a) $Z = 0{,}5 ZI$ cm^3 (b) $Z = 4{,}85 H_c s\, l_e^2$ cm^3
Symbols		
L, B, D, T, C_b, H_c, l_e, S, s, t and Z are as defined in 1.5.1 and Table 1.7.1 $P_0 = 1{,}8\sqrt{\left[\frac{B}{r}(T C_b - 0{,}16D)\right]}$ t/m^2 r = ratio cargo compartment length, in metres/L		
NOTE The application of higher tensile steel inner bottoms will be specially considered.		

■ *Section 9* Additional requirements for container ships

9.1 Double bottom structure, general

9.1.1 The minimum scantlings of structural members of single and double bottoms are to comply with the requirements of Sections 6 and 7, as applicable, but are to be confirmed by direct calculations in accordance with this Section.

9.1.2 A minimum container mass of 15 tonnes should be taken into account for either 20 ft or 40 ft containers. This figure is to be multiplied with the number of tiers of containers intended to be carried. Where it is intended to carry more than 4 tiers, the upper tier may be assumed empty. As an example, in case of a ship designed to carry 4 tiers of containers, a minimum stackload of 60 tonnes will need to be used. The bottom structure may be designed for higher stack loads as desired. The values of allowable container stack loadings are to be supplied to the ship.

9.1.3 The requirements given in this Section are based on the assumption that continuous girders are fitted under the container corners.

9.1.4 Local stiffening will be required under container corners, and the locations of the corners are to be clearly marked in the inner bottom plating or hold ceiling when no permanent container corner seatings are provided on the inner bottom.

9.1.5 Additional requirements regarding the double-bottom structure are given in 9.3, 9.4 and 9.5.

9.2 Torsional strength

9.2.1 The mass of the containers is to be evenly distributed over the width of the ship, thus preventing high torsional moments being imposed. If high torsional moments are foreseen or are to be incorporated in the design the values of these torsional moments are to be indicated on the structural plans of the cargo part and on the midship section plan. In such cases, the torsional strength of the ship will be specially considered.

9.3 Girders in the double bottom

9.3.1 Where no centreline girder is fitted, adequate support on the centreline must generally be provided for docking purposes.

9.3.2 Partial girders may be required close to the bottom girders to spread the container loads locally over the bottom structure. The partial girders in way of the container corners as indicated in Fig. 1.9.1 and Fig. 1.9.2 are to have the same thickness as the continuous girders.

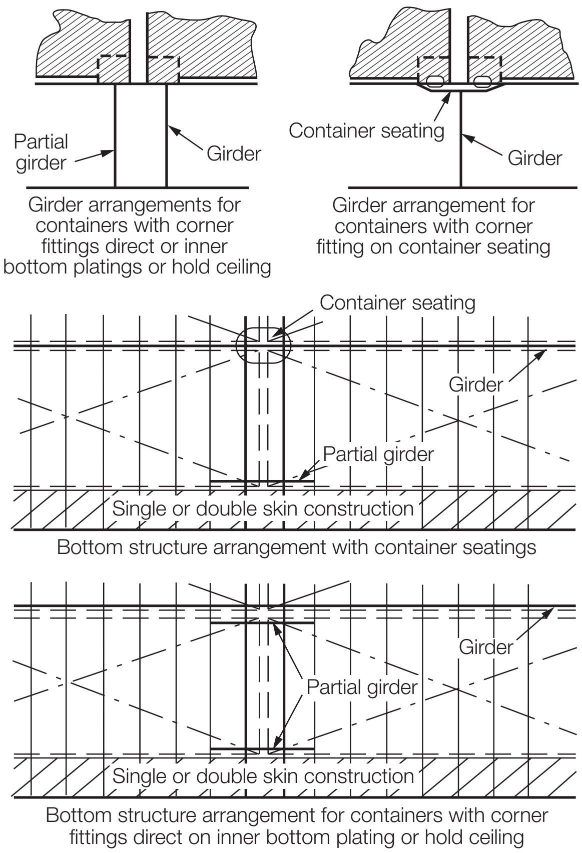


Fig. 1.9.1 Schematic bottom structure

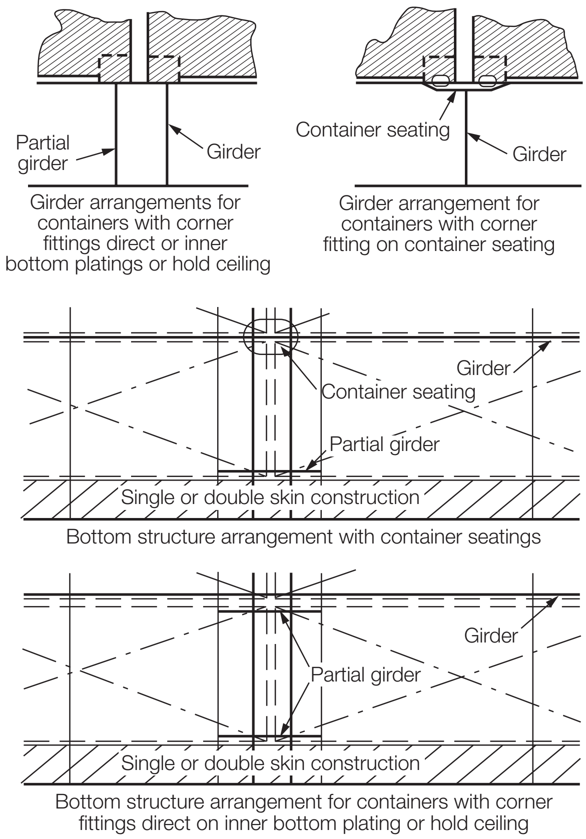


Fig. 1.9.2
Schematic bottom structure (longitudinal framing)

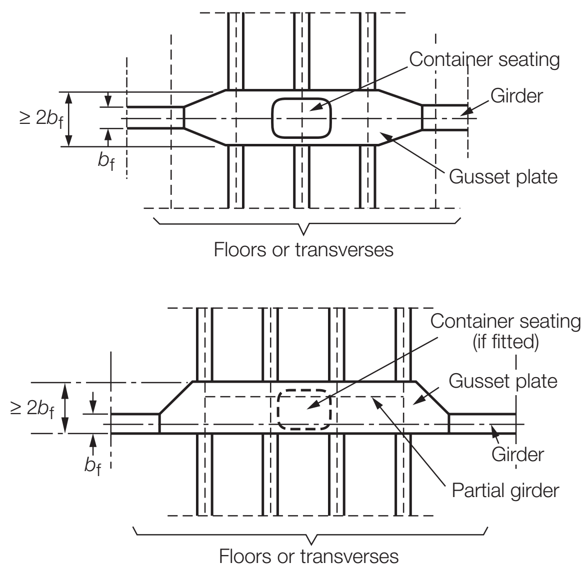
9.3.3 In single bottoms, in way of the container corner fittings, gusset plates are to be fitted connecting the floors or transverses to the longitudinal girders. The gusset plates are to extend over at least three floors or transverses and are to be tapered off in the fore and aft direction. *See* Fig. 1.9.3.

9.4 Double bottom floors and transverses

9.4.1 In a longitudinal framing system, floors or transverses are to be fitted at a spacing not exceeding 2,0 m. Special attention is to be paid to the distribution of shearloads and resulting shear stresses in floors and longitudinal girders directly loaded by containers, and this aspect is to be verified by direct calculations. Where necessary, additional panel stiffeners or web plating of increased thickness may need to be fitted in order to prevent local plate buckling.

9.4.2 Special attention should be paid to the shear strength of floors under container fittings in way of the connection with the side shell structure. For this purpose, the web thickness may require to be locally increased.

9.4.3 Where a double hull has been provided, the inner bottom plating in way of the floors is to be suitably scarphed into the double hull structure by means of horizontal gusset plates or equivalent.



Thickness of gusset plates is to be not less than thickness of faceplates of floors, transverses or girders, whichever is the greater

Fig. 1.9.3 Gusset plate arrangements

9.5 Assessment of bottom structure by direct calculation

9.5.1 The scantlings of the bottom structure are to be determined by direct calculations in accordance with this sub-Section, together with procedures and criteria as outlined in Section 13.

9.5.2 The calculation is to be carried out as a finite element analysis of the bottom structure, generally covering the bottom structure extending over one container length. Smaller extents, i.e. half container lengths may be used depending on the degree of uniformity of the bottom structure.

9.5.3 The analysis of the bottom structure is to be carried out for the bottom loaded by container point loads (for 20 ft and 40 ft containers as applicable) whereby the draught of the ship is to be taken not greater than 0,4T for ships with loading sequence notation LS'O' and 0,6T for ships with notations LS'T' or LS'D'.

9.6 Stability

9.6.1 For ships navigating on the Rhine, attention is drawn to the intact stability requirements as contained in the Rhine Inspection regulations.

■ *Section 10* Single side shell and deck supporting structure

10.1 General

10.1.1 This Section covers the arrangements and requirements for one of the following transverse framing systems:

(a) Support of the side shell and deck by framing of equal profile depth only.

(b) Support of the side shell and deck by a combination of frames and web frames or bulkheads.

10.1.2 The scantlings of the side shell structural parts, viz. frames, web frames and the brackets under deck from frame to coaming are to comply with Table 1.10.1.

10.1.3 Where a longitudinal framing system is adopted, the scantlings and arrangements will be specially considered.

10.2 Frames

10.2.1 In ships with a single bottom, the lower end of the frames is to overlap the floors. In ships with a double bottom, the lower end of the frame is to be efficiently connected to the double bottom structure.

10.3 Web frames

10.3.1 If web frames are fitted, they are to be spaced not more than 5 m apart. The thickness, stiffening arrangement and end connections of web frames are to be in accordance with the requirements of Pt 3, Ch 10,4.

10.4 Brackets under deck

10.4.1 At the head of frames and web frames, brackets are to be fitted supporting deck and hatch coaming. The arrangements of the brackets is shown in Fig. 1.10.1. The scantlings of the brackets at the frames and web frames are to have equal dimensions, it being assumed that the load from coaming and deck is evenly distributed over each bracket. Proposals for other structural arrangements resulting in a different distribution of loads will be specially considered. Where a travelling crane for the lifting of hatch covers or cargo is used, the load from the crane is also to be taken into account when calculating the bracket scantlings.

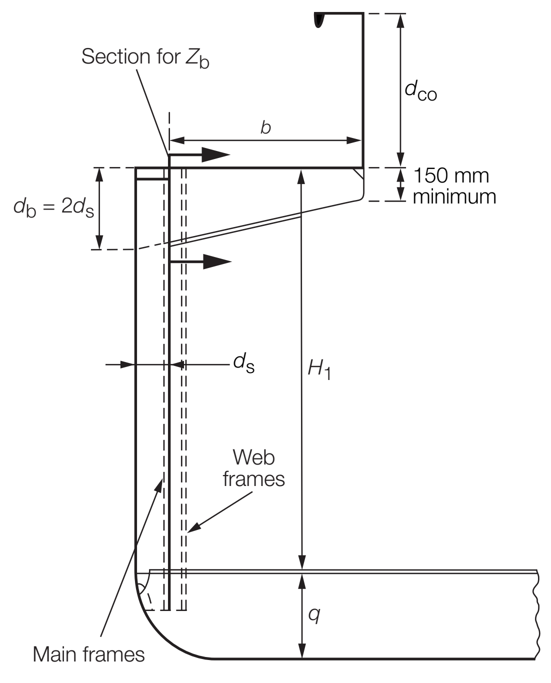


Fig. 1.10.1 Frame arrangement

Table 1.10.1 Single skin construction

Item	Parameter	Requirement
(1) Frames	Modulus	$Z_f = 1{,}5 k_1\, s\, T_1^3 \left(10 + 3 \left(\dfrac{T_1}{H_1}\right)^2 - \dfrac{10 T_1}{H_1}\right) + Z_b$
(2) Web frames	Modulus	$Z = 5{,}6 S \dfrac{T_1^4}{H_1^2} \left(5 H_1 - 2 T_1\right) + Z_b$
(3) Brackets under deck	Depth Thickness Flange width Minimum required modulus	d_b = as shown in Fig. 1.10.1 $t = 4 + 0{,}3\, Z_f$ mm b_f = 70 mm minimum $Z_b = 29 k_2 \times b \times s\, (b \times h_1 + b_1 \times h_h)$ cm^3
Symbols		
D, T, S, s, t and Z are as defined in 1.5.1 b = width of bracket, in metres, as shown in Fig. 1.10.1 b_f = width of bracket flange, in mm b_1 = width of hatchway, in metres h_h = head, in metres, on the hatch covers (if fitted) as defined in Pt 3, Ch 3,4 h_1 = head on deck, in metres, as defined in Pt 3, Ch 3,4 k_1 = 1 + (u – 15) x 0,078, but this factor is to be not less than 1, nor greater than 3,33, where u = distance between transverse bulkheads, web frames or other efficient transverse supports, in metres k_2 = $L_{co}/12d_{co} - 1$, but this factor is to be taken not less than 0, nor greater than 1, where L_{co} = length of hatch coaming between transverse bulkheads, or other efficient vertical supports, in metres d_{co} = depth of hatch coaming, in metres, as shown in Fig. 1.10.1 q = height of single or double bottom, in metres, as shown in Fig. 1.10.1 H_1 = vertical framing depth, in metres, as shown in Fig. 1.10.1 T_1 = $D - q$ but need not be taken greater than $T + 0{,}4 - q$, in metres Z_b = modulus, in cm^3, of brackets under deck at the intersection with the frame as indicated in Fig. 1.10.1 Z_f = modulus of the frame, in cm^3		
NOTES 1. Where frames do not support cantilever brackets under deck, a minimum value of 15 cm^3 for Z_b is to be applied. 2. Z_b is to be obtained from (3) taking k_2 = 1 and s as the spacing between web frames. 3. If the factor k_2 is 0, the frame bracket may also be replaced by a deck beam with a section modulus not less than half the section modulus of a frame and suitably connected to the frame.		

■ *Section 11* Double skin structure

11.1 General

11.1.1 This Section covers the arrangements and requirements for transversely and longitudinally framed side shell structures of double skin ships.

11.1.2 The scantlings of the double skin structure, except side shell plating, are to comply with Table 1.11.1. For side shell plating, *see* Section 5.

11.1.3 The side shell may be transversely or longitudinally framed. The longitudinal bulkheads are in general to have the same framing system as the shell.

11.2 Transverse framing

11.2.1 The lower ends of side frames and stiffeners of longitudinal bulkheads may overlap the floors or otherwise be connected to the floors or tank top by means of brackets. At their upper ends, side frames and bulkhead stiffeners are to be interconnected by mean of brackets, *see* Fig. 1.11.1.

11.2.2 In addition to the frames, plate webs are to be fitted spaced not more than 8 m apart, *see also* Fig. 1.11.2(a). Manhole openings are to be provided in the plate webs to allow for inspection. Horizontal stiffeners are to be fitted to the plate webs, spaced not more than twice the frame spacing apart. Plate webs with large access holes are to be additionally stiffened and their scantlings are to be verified by direct calculations. The scantlings of truss-type web frames, replacing plate webs and composed of rolled or built sections, are to be determined by direct calculation.

11.2.3 Alternatively, plate webs in accordance with 11.2.2 may be fitted at every frame.

Table 1.11.1 Double skin structure (General requirements)

Item	Parameter	Requirement
(1) Shell frames	Modulus	$Z_f = 1{,}5k_1\, s\, T_1{}^3 \left(10 + 3\left(\dfrac{T_1}{H_1}\right)^2 - \dfrac{10T_1}{H_1}\right) + 2H_1\, Ts\sqrt{B}$
(2) Vertical stiffeners on longitudinal bulkhead	Modulus	$Z = Z_f$
(3) Brackets under deck	Depth Thickness Flange width	d_b as shown in Fig. 1.11.1 $t = 4 + 0{,}3\sqrt{Z_f}$ mm $b_f \geq 70$ m
Longitudinal framing systems		
(4) Shell longitudinals	Modulus	$Z = (4{,}6 + 0{,}0342L_1)\, h_s \times s \times l_e{}^2$, *see* Note 1
(5) Horizontal stiffeners on longitudinal bulkhead	Modulus	$Z_l = 8D\, s\, l_e{}^2$, *see* Note 1
(6) Web frames at shell, *see* Fig. 10.11.3	Modulus	$Z_W = 1{,}2T_1{}^3\, S\left(7 - \dfrac{4T_1}{H_1}\right)$ cm^3
(7) Web frames on longitudinal bulkhead, Fig. 10.11.3	Modulus	$Z = Z_W$
(8) Bracket under deck	Depth Thickness Flange width	d_b as shown in Fig. 1.11.1 $t = 4 + 0{,}3\sqrt{Z_f}$ mm $b_f = 70$ m
Transverse and longitudinal framing systems		
(9) Plating of longitudinal bulkhead, *see* Notes 2 and 3	Thickness	$t = (5{,}6 + 054L)\sqrt{s}$
(10) Plate webs, *see* Fig. 1.11.2 Thickness	The greater of	$t = 7$ mm $t = 10s_d$ $t(c) = 2 + 2{,}8\,D$
(11) Horizontal stiffeners on webs	Width Thickness	$W = 125b$ mm t = thickness plate webs
Symbols		

L, B, D, T, S, s, t, Z and I are as defined in 1.5.1

b = breadth of side shell structure, in metres, as indicated in Fig. 1.11.2
h_s = $h_{de} + h_t$ but not less than 2,0 m
h_{de} = distance of longitudinal to the deck at side, in metres
h_t = 0 for void spaces
0,50 for deeptanks but not less than the distance to the top of the overflow
q = height of single or double bottom, in metres, as shown in Fig. 1.11.1
s_1 = spacing between horizontal stiffeners, in metres
s_d = stiffener spacing or width of double skin, whichever is the smaller
t_s = thickness of side shell, in mm
H_1 = vertical framing depth, in metres, as shown in Fig. 1.11.1 and Fig. 1.11.2
L_1 = L, but is to be taken as not less than 50 m nor more than 100 m
S_b = spacing of plate webs, in metres
T_1 = $D - q$, but need be taken not greater than $T + 0{,}4 - q$, in metres
Z_f = modulus of frame, in cm^3
Z_l = modulus of side shell longitudinal, in cm^3
Z_w = modulus of web frame, in cm^3

NOTES
1. The web thickness of longitudinals is not to be less than 7 mm.
2. For bulkcarriers it is recommended to add 3 mm to the thickness of the lower edge of the bulkhead over a height of about 250 mm above the inner bottom.
3. The thickness of the upper strake of the longitudinal bulkhead may require to be increased to satisfy the hull girder bending stress criteria in Pt 3, Ch 4.

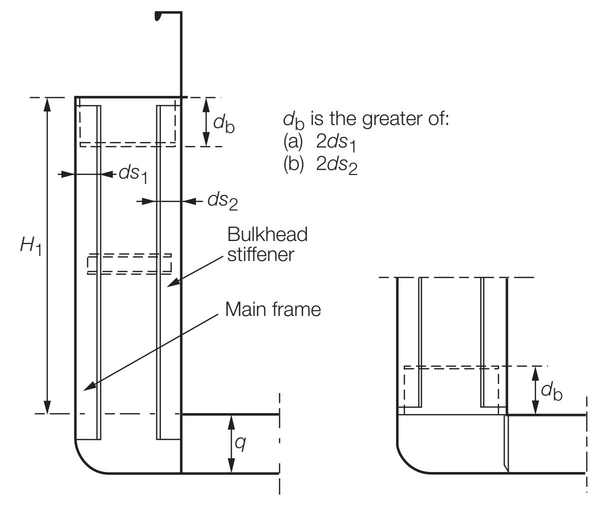


Fig. 1.11.1 Frame arrangement (transverse framing)

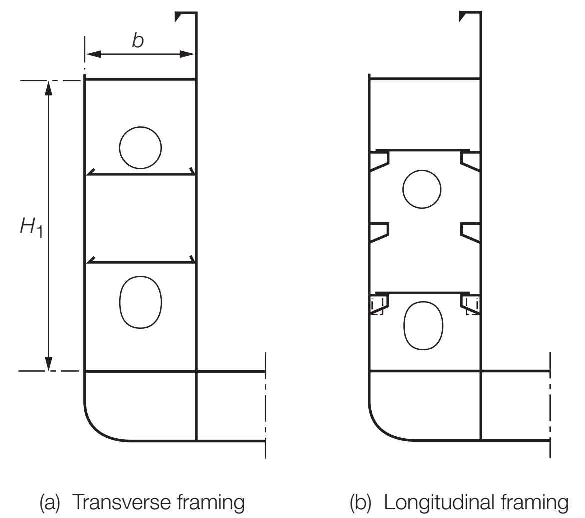


Fig. 1.11.2 Arrangement of plate webs

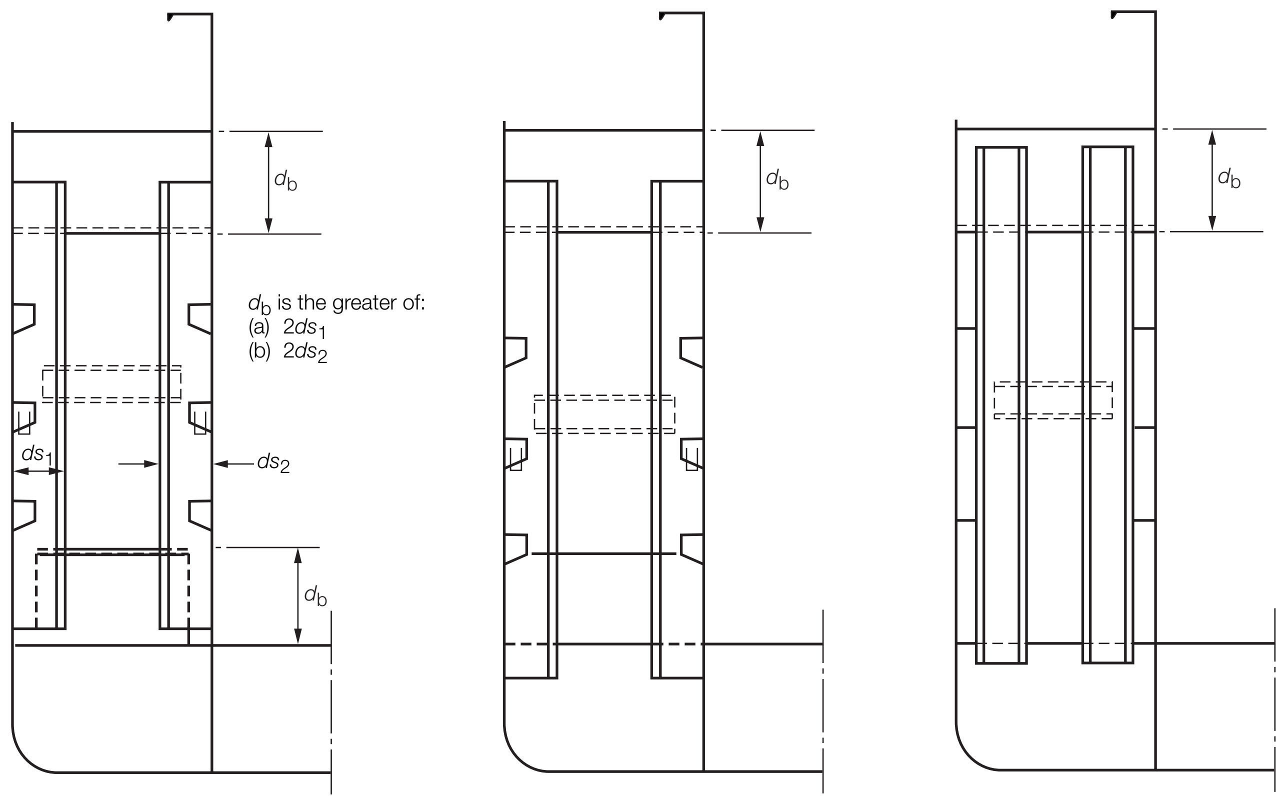


Fig. 1.11.3 Arrangement for web frames

11.3 Longitudinal framing

11.3.1 Longitudinals on shell and longitudinal bulkheads are to be supported by web frames, spaced not more than 2,5 m apart, and efficiently connected thereto.

11.3.2 Web frames are to be fitted in line with plate floors and are generally to be constructed as indicated in Fig. 1.11.3. The lower ends of the web frames may overlap the floors or are otherwise to be connected to the floors or tank top by means of brackets. At their upper ends, web frames are to be interconnected by means of brackets, *see also* Fig. 1.11.3.

11.3.3 In addition to the web frames as required by 11.3.2, plate webs are to be fitted not more than 8 m apart, *see also* Fig. 1.11.2(b). Manhole openings are to be provided in the plate webs to allow for inspection. Horizontal stiffeners are to be fitted to the plate webs spaced not more than twice the frame spacing apart. Plate webs with large access holes are to be additionally stiffened and their scantlings are to be verified by direct calculations.

11.3.4 As an alternative to the web frames required by 11.3.2, plate webs in accordance with 11.3.3 may be fitted.

11.4 Longitudinal bulkhead

11.4.1 The scantlings of the longitudinal bulkhead are to comply with Table 1.11.1.

11.4.2 Where the longitudinal bulkhead is not connected to the bottom shell but supported by the bottom floors, vertical stiffeners are to be fitted to the floors and connected to the inner bottom plating in line with the longitudinal bulkhead.

11.4.3 The ends of the longitudinal bulkheads are to be well scarfed into the ship's fore and aft structure.

11.5 Watertight sub-division

11.5.1 It is recommended that Owners consider subdividing the space between side shell and longitudinal bulkhead such that the ship remains afloat when one of the compartments becomes flooded.

11.5.2 For ships navigating on the Rhine with an overall length greater than 110 m, compliance with damage stability requirements are mandatory in accordance with the Rhine Inspection Regulations.

11.5.3 For ships carrying dangerous goods, *see also* Section 12.

■ *Section 12*
Additional requirements for ships carrying dangerous goods

12.1 General

12.1.1 This Section applies to ships which are to be built in accordance with the additional requirements set out in Chapter 9, Section 9.1.0.80 of the ADNR/ADN. Ships complying with the requirements of this Section will be eligible to receive the additional Class Notation in accordance with 1.3.5.

12.1.2 The ADNR and ADN are the regulations for the transport of dangerous goods on European waterways. The abbreviation **ADN** stands for:

Accord européen relatif au transport international des marchandises **D**angereuses par voie de **N**avigation intérieure.
The letter '**R**' was added and stands for Rhine.

12.1.3 The exemptions and derogations to the ADN and to the ADNR, as authorized by the CCNR, may also be taken into consideration.

12.1.4 The structural and other arrangements of dry cargo ships for the carriage of dangerous goods in bulk, to be registered in, or to operate in countries with Regulations differing from ADN and ADNR will receive appropriate special consideration if required by the relevant Authorities and/or desired by the Owner.

12.1.5 At the time of publishing of these Rules, the ADNR was still in force as the governing regulations concerning the transport of dangerous goods on the river Rhine. In terms of it's validity on the river Rhine it is, however, foreseen that the ADNR will eventually be replaced by the ADN. Until then, subsequent references to the ADN in further paragraphs can also be considered as being references to the ADNR, as long as the ADNR has not been superseded by the ADN.

12.1.6 Although the contents of this Section take the ADN and ADNR Regulations into account, the issue of an ADN or ADNR Certificate on behalf of the Relevant Authorities requires full compliance with their Regulations.

12.1.7 For ease of reference, the relevant Parts of which the ADNR/ADN consists are given hereunder:

Part 1	General provisions
Part 2	Classification (of dangerous goods)
Part 3	Lists of dangerous goods and special requirements
Part 4	Provisions concerning the use of packagings and tanks
Part 5	Consignment procedures
Part 6	Requirements for the construction and testing of packagings (including IBCs and large packagings) and tanks
Part 7	Requirements concerning loading, carriage, unloading and handling of cargo
Part 8	Provisions for the crew, certain equipment, operation and documentation
Part 9	Rules for construction.

12.1.8 For further details and information, reference is made to the above Parts of the ADNR/ADN. For use together with this Chapter, special attention is drawn to the contents of Parts 2, 3, 7 and 9 of the ADNR/ADN.

12.2 Dangerous goods

12.2.1 The following categories of dangerous goods are identified in Part 2 of the ADNR/ADN:

Class 1	Explosive substances and articles
Class 2	Gases
Class 3	Flammable liquids
Class 4.1	Flammable solids, self-reactive substances and solid desensitized explosives
Class 4.2	Substances liable to spontaneous combustion
Class 4.3	Substances which, in contact with water, emit flammable gases
Class 5.1	Oxidizing substances
Class 5.2	Organic peroxides

Class 6.1	Toxic substances
Class 6.2	Infectious substances
Class 7	Radioactive material
Class 8	Corrosive substances
Class 9	Miscellaneous dangerous substances and articles.

12.2.2 Table A as listed in Part 3 of the ADNR/ADN contains the list of dangerous goods in numerical order (UN number or identification number). This Table also contains data concerning the permitted form of carriage in inland waterways vessels.

12.3 Limiting quantities of dangerous goods

12.3.1 Part 7 of the ADNR/ADN contains requirements concerning the maximum quantities of dangerous goods of Classes 2, 3, 4.1, 4.2, 4.3, 5.1, 5.2, 6.1, 7, 8 and 9 which may be carried on one ship.

12.3.2 Ships intended to carry dangerous goods of Classes 2, 3, 4.1, 5.2, 6.1, 7, 8 or 9 – except those for which label No. 1 is prescribed in column (5) of Table A of Ch 3,2 – in quantities exceeding those referred to in paragraph 7.1.4.1.1 of the ADNR/ADN, shall also comply with the requirements of 12.4, 12.5, 12.6 and 12.7.

12.4 Structural requirements

12.4.1 The ship shall be built as a double-hull vessel with double-hull spaces and a double bottom within the protected area.

12.4.2 The distance between the sideshell and the cargo hold bulkheads shall not be less than 0,80 m.

12.4.3 The depth of the double bottom shall be not less than 0,50 m. The depth below a suction well may however be locally reduced to 0,40 m. When the distance of the bottom of the suction well is between 0,40 and 0,49 m from the base-line the horizontal cross sectional area of the well shall not exceed 0,50 m^2. In all cases the volume of the well shall not exceed 0,12 m^3

12.4.4 Regardless of statutory requirements relating to the width of walkways on deck, a reduction of the distance as per 12.4.2 to 0,60 m is permitted, provided that the following reinforcements will be provided:

(a) Where the vessel's sides are constructed according to the longitudinal framing system, the frame spacing shall not exceed 0,60 m. The longitudinals shall be supported by plate webs in line with the floors in the double bottom. Plate webs are to be provided with openings to enable proper inspection of the space. The webs are to be spaced not more than 1,80 m apart. This distance may be increased when the structure is strengthened accordingly;

(b) Where the vessel's sides are constructed according to the transverse framing system,
either:
- two longitudinal side shell stringers shall be fitted. The distance between the two stringers and between the uppermost stringer and the deck at side shall not exceed 0,80 m. The depth of the stringers shall be at least equal to that of the transverse frames and the cross-section of the face plate shall be not less than 15 cm^2. The longitudinal stringers shall be supported by open plate webs in line with the plate floors in the double bottom and spaced not more than 3,60 m apart. The transverse sideshell frames shall be connected at the bilge by a bracket having a depth not less than 0,90 m and a thickness equal to the thickness of the floors;

or:
- open plate webs in line with the double bottom floors shall be arranged at each transverse frame;

(c) The upper deck shall be supported by transverse bulkheads or cross-ties spaced not more than 32 m apart. This requirement may be waived provided it is proven that the (additional) structure in the double hull is such that adequate transverse strength is achieved.

12.5 Arrangements

12.5.1 The bottom of the holds shall be such as to permit them to be cleaned and dried.

12.5.2 Cargoholds shall have no common bulkheads with oil fuel tanks.

12.5.3 The air pipes of all oil fuel tanks shall be led to 0,50 m above the open deck.

12.5.4 Means are to be provided to prevent the formation of sparks in the protected area.

12.5.5 Entrances to and openings of engine rooms and service spaces shall not face the cargo area.

12.5.6 Openings of the accommodation and wheelhouse facing the cargo holds are to be provided with gastight closing appliances.

12.5.7 Exhausts shall be led into the open air either upwards through an exhaust pipe or through the shell plating. The exhaust outlet shall be located not less than 2,0 m from the cargo hold openings. The exhaust pipes of engines shall be arranged in such a way that the exhausts are led away from the vessel. The exhaust pipes shall not be located within the protected area.

12.6 Ventilation

12.6.1 Ventilation shall be provided for the accommodation and for service spaces.

12.6.2 Ventilation ducts for venting the hold(s) shall be positioned at the extreme ends of the hold(s) and extend down to not more than 50 mm above the bottom. The extraction of gases and vapours through the duct shall also be ensured in case of carriage of bulk cargoes.

12.6.3 If the ventilation ducts are removable they shall be suitable for the ventilator assembly and capable of being firmly fixed. Protection shall be ensured against bad weather and spray. An unobstructed intake of air shall be ensured during ventilation.

12.7 Stability

12.7.1 Attention is drawn to the ADNR/ADN damage stability requirements. Verification of compliance with these regulations is usually dealt with by the National Authorities, but upon request, verification by the Society followed by issuing a statement of compliance can also be arranged.

■ *Section 13* Direct calculation procedures

13.1 General

13.1.1 This Section contains guidance for direct calculations, information regarding maximum permissible stresses and minimum requirements for structural members included in the hull midship section modulus and for other structural members which do not form part of the hull midship section modulus.

13.1.2 Where direct calculation is adopted as an alternative of scantlings derived by Rule formulae, or for the asessment of scantlings of structural members not covered by the Rules, all data in support of the calculation, i.e. support conditions and loads are to be submitted for approval together with the calculation.

13.2 Permissible stresses

13.2.1 In addition to the permissible stresses given in Pt 3, Ch 4,6, the following stress criteria are to be applied:

(a) For structural members included in the hull section modulus the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in Table 1.13.1.
(b) For structural members not included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in Table 1.13.2.

13.2.2 Where finite plate element calculations are carried out, local peak stresses in excess to those given in 13.2.1 will be specially considered.

Table 1.13.1 Maximum permissible stresses in longitudinal continuous members, in N/mm²

Item	Local bending stress, σ_b	Combined bending stress, σ_c, *see* Note 1	Shear stress τ	Equivalent stress, σ_e, *see* Note 2
Bottom girders	110	180	85	190
Bottom longitudinals, Inner bottom longitudinals, Side shell longitudinals	140	180	85	190

NOTES
1. The combined stress, σ_c, is the sum of the stress due to longitudinal bending and local loading.
2. The equivalent stress, σ_e, is to be calculated according to the formula $\sigma_e = \sqrt{(\sigma_c^2 + 3\tau^2)}$

Table 1.13.2 Maximum permissible stresses in local members in N/mm²

Item	Bending stress, σ_b	Shear stress, τ	Equivalent stress, σ_e *see* Note
Floors, non-continuous bottom girders, non-continuous deck girders, deck transverses, cantilever brackets	130	85	180

NOTE
The equivalent stress, σ_e, is to be calculated according to the formula $\sigma_e = \sqrt{(\sigma_c^2 + 3\tau^2)}$

13.3 Structural requirements

13.3.1 As a first approximation the structural components may be determined according to the requirements of the preceding Sections of this Chapter.

13.3.2 In addition to the maximum permissible stresses given in this Section, the following minimum plating thickness requirements are to be complied with. The thickness of bottom, bilge and side shell plating amidships is to be not less than required by Table 1.5.1. The minimum thickness of the deck plating and coaming plating is to be not less than required by Table 1.4.1. Depending on the level of compressive stresses, additional buckling calculations may be required.

Section

Section 1 General

1.1 Application

1.1.1 This Chapter applies to ferries and roll on-roll off ships defined as follows:

(a) A ferry is a self-propelled ship, designed primarily for the carriage of vehicles and/or passengers on a regular scheduled service of short duration.

(b) A roll on-roll off ship is a self-propelled ship with machinery aft or a non-propelled ship, designed primarily for the carriage of vehicles and for cargo loaded/unloaded by wheeled vehicles.

1.1.2 The structural requirements of this Chapter are intended to cover the midship region, as defined in Pt 3, Ch 3,2.2 for ships having a length not exceeding 125 m, a ratio of length to depth not exceeding 33 and a ratio of breadth to depth not exceeding five.

1.1.3 Arrangements and scantlings forward and aft of the midship region are to comply with Pt 3, Ch 5 and Ch 6 so far as applicable. The remaining requirements of Part 3 are also to be complied with, as appropriate to the intended arrangements.

1.1.4 The scantlings and arrangements are to be as required in Chapter 1 as far as applicable or as specified otherwise in this Chapter.

1.1.5 For ferries carrying passengers, the requirements of Chapter 9 are also to be complied with so far as applicable.

1.2 Structural configuration

1.2.1 This Chapter provides for a basic structural configuration of a single flush deck or a multi-deck hull with a single or double bottom arrangement and a single skin side construction, *see* Fig. 2.1.1, and for a basic structural configuration of a single deck hull with a long wide hatch opening, a double bottom and a double skin side construction, *see* Fig. 2.1.2.

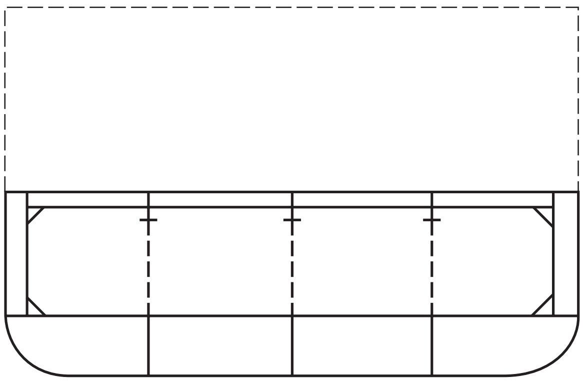


Fig. 2.1.1
Configuration with single flush deck or a multi-deck hull with a single or double bottom arrangement and a single skin side construction

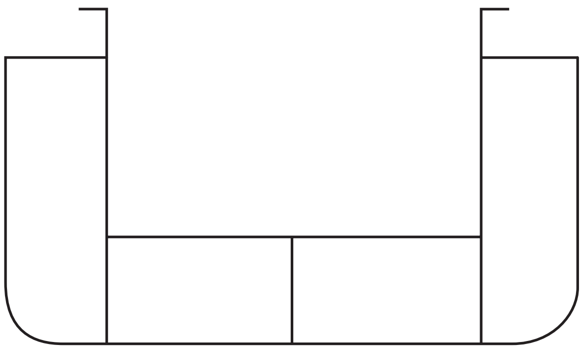


Fig. 2.1.2
Configuration of a single deck hull with a long wide hatch opening, a double bottom and a double skin side contruction

1.2.2 Longitudinal or transverse framing may be adopted. Ships with a ratio of length to depth exceeding 25 or a length, *L*, over 70 m and having a double bottom are generally to be constructed with longitudinal framing in the bottom. Alternatively, transverse framing may be adopted provided suitable longitudinal stiffening is fitted to the bottom plating.

1.2.3 The number and disposition of transverse bulkheads are to be as required by Pt 3, Ch 7. Additional bulkheads many have to be fitted to provide for sufficient transverse strength of the ship. Web frames are to be fitted in line with deck transverses and floors, forming a ring system.

1.3 Class notations

1.3.1 Ships complying with the relevant requirements of this Chapter will be eligible to be classed ‘A1 I.W.W. ferry’, ‘A1 I.W.W. roll on-roll off ship’ or ‘A1 I.W.W. roll on-roll off barge’, whichever is applicable.

1.3.2 The Regulations for classification and assignment of class notations are given in Pt 1, Ch 2, to which reference should be made on the survey request form.

1.3.3 Where a ship has been specially designed, modified and/or arranged in accordance with the additional requirements for Zones 2 or 1, for service extension, for any special loading or discharging sequence or for navigation in ice, the appropriate class notation will be assigned.

1.4 Information required

1.4.1 For the information required, *see* Pt 3, Ch 1,5. In addition, the following are to be supplied:

(a) Cargo loading on inner bottom, hatchways and decks if this is in excess of the Rule loading, *see* Pt 3, Ch 3,4.
(b) Details of wheeled vehicles to be used, *see* Pt 3, Ch 9,2.2.
(c) The maximum pressure head in service on tanks, also details of any tanks interconnected with side tanks if fitted.
(d) Details of tanks which will be solely used for water ballast in the light condition and which will be empty in the loaded condition.

1.5 Symbols and definitions

1.5.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D and *T* are as defined in Pt 3, Ch 1,6.1

l = overall length of stiffening member, in metres, *see* Pt 3, Ch 3,3.2
l_e = effective length of stiffening member in metres, *see* Pt 3, Ch 3,3.3
s = spacing of secondary stiffeners, i.e. frames, beams or stiffeners, in metres
t = thickness of plating, in mm
I = inertia of stiffening member, in cm^4, *see* Pt 3, Ch 3,3.2
S = spacing or mean spacing of primary members, i.e. girders, transverses, webs, etc., in metres
Z = section modulus of stiffening member, in cm^3, *see* Pt 3, Ch 3,3.2.

■ Section 2
Longitudinal strength

2.1 General

2.1.1 The longitudinal strength of the ship is to comply with the requirements of Pt 3, Ch 4 and for this purpose a ferry or roll on-roll off ship is to be considered as a Category 'O' ship.

2.1.2 The ratio of cargo compartment length, *L*, is to be taken as 0,73.

■ Section 3
Topside structure and deck structure

3.1 General

3.1.1 The topside structure for ships of a structural configuration according to Fig. 2.1.2 is to comply with Ch 1,4.

3.1.2 Where a ship has a structural configuration according to Fig. 2.1.1, the deck plating and deck supporting structure is to comply with the requirements of Tables 2.3.1 and 2.3.2 respectively, but in ships over 40 m in length, the thickness of deck plating may require to be increased to obtain the midship section modulus as required in Pt 3, Ch 4.

3.1.3 The parts of the deck used by wheeled vehicles are also to comply with the requirements of Pt 3, Ch 9,2.

3.2 Deck plating

3.2.1 Where hatch openings are made in the deck plating, compensation will be required for the material cut out. However, no compensation need be fitted if the loss of sectional area has already been taken into consideration in calculating the actual midship hull section modulus. Plate panels, in which openings are cut, are where necessary, to be adequately stiffened against compression.

3.3 Deck supporting structure

3.3.1 Scantlings given in Table 2.3.2 are based on end connections in accordance with Pt 3, Ch 10,3. Where brackets having arm lengths differing from the standard are fitted, the modulus of the stiffening member is to be corrected in accordance with Pt 3, Ch 10,3.7.

3.3.2 Deck girders and transverses may be fitted in conjunction with load-bearing bulkheads or pillars for support of deck beams and deck longitudinals. Where tracked vehicles are proposed, girders are to be fitted under the trackways.

3.3.3 Pillars are to be fitted in the same vertical line wherever possible, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

3.4 Truss arrangements

3.4.1 Truss arrangements comprising top and bottom girders or transverses in association with pillars and diagonal bracing, may be fitted to support the bottom and deck structure. The diagonal members are generally to have angles of inclination with the horizontal of 45° and a cross-sectional area of not less than 50 per cent of the adjacent pillar.

Table 2.3.1 Deck plating

<table>
<tr><th>Item and parameter</th><th>Longitudinal framing</th><th>Transverse framing</th></tr>
<tr><td rowspan="3">Deck plating
Thickness</td><td>The greater of:
$t = (5{,}6 + 0{,}039L)\sqrt{s}$ mm

$t = 10s$ mm
See Note 2 in Table 2.3.2</td><td>The greater of:
$t = (5{,}6 + 0{,}039L)\sqrt{s}$ mm

$t = 10s$ mm
See Note 2 in Table 2.3.2</td></tr>
<tr><td colspan="2">but for ships with a length, L, exceeding 40 m, t is to be not less than:</td></tr>
<tr><td>The greater of:
$t = 0{,}076 \dfrac{M}{B \times D} - \dfrac{a_1}{10B}$ mm

$t = 2{,}3 \sqrt[3]{\dfrac{MS \times s^2}{B \times D}}$ mm</td><td>The greater of:
$t = 0{,}076 \dfrac{M}{B \times D}$ mm

$t = 3{,}85 \sqrt[3]{\dfrac{MS \times s^2}{B \times D \times C_1}}$ mm</td></tr>
</table>

Table 2.3.2 Deck supporting structure

<table>
<tr><th>Item</th><th>Parameter</th><th>Requirements</th></tr>
<tr><td>(1) Deck beams</td><td>Modulus</td><td>$Z = 4{,}3h_1\, s\, l_e^2 + 4$ cm^3</td></tr>
<tr><td>(2) Deck longitudinals</td><td>Modulus</td><td>$Z = (1{,}45 + 0{,}07L_1)\, h_1\, s\, l_e^2$ cm^3</td></tr>
<tr><td>(3) Deck girders</td><td>Modulus

Inertia</td><td>$Z = (1{,}35 + 0{,}085L_1)\, h_1\, s\, l_e^2$ cm^3

$I = 2{,}3l_e\, Z$ cm^4</td></tr>
<tr><td>(4) Deck transverses</td><td>Modulus</td><td>$Z = 4{,}75h_1\, s\, l_e^2$ cm^3</td></tr>
<tr><td>(5) Pillars</td><td>Cross-sectional area

Minimal wall thickness of hollow pillars</td><td>$A_p = \dfrac{P}{1{,}26 - 4{,}2\dfrac{l}{r}}$ cm^2

The greater of:
(a) $t = 0{,}033d_p$ mm for tubular pillars
$t = 0{,}056b$ mm for square pillars
(b) $t = 5$ mm</td></tr>
<tr><td colspan="3">Symbols applying to Tables 2.3.1 and 2.3.2</td></tr>
<tr><td colspan="3">L, B, D, S, s, l_e, Z, I and t are as defined in 1.5.1
a_1 = total area of deck longitudinals, in cm^2
b = breadth of side of a hollow rectangular pillar, in mm
d_p = mean diameter of tubular pillars, in mm
h_1 = head on deck, in metres, as defined in Pt 3, Ch 3,4
l = overall length of pillar, in metres
r = least radius of gyration of pillar cross-section, in mm, and may be taken as:
$r = 10 \sqrt{\dfrac{I_p}{A_p}}$
A_p = cross-sectional area of pillar, in cm^2
$C_1 = 1 + 3\left(\dfrac{s}{S}\right)^2$, where $\dfrac{s}{S}$ is the ratio of the unstiffened deck panel under consideration
I_p = least moment of inertia of cross-section, in cm^4
L_1 = L, but is to be not less than 40 m, nor more than 100 m
M = the greater of MS and MH
MH = maximum design hogging moment, in tm, see Pt 3, Ch 4
MS = maximum design sagging moment, in tm, see Pt 3, Ch 4
P = load supported by the pillar, in tonne-f</td></tr>
<tr><td colspan="3">NOTES
1. The deck structure is also to comply with the requirements of Pt 3, Ch 9,2 for the parts of the deck used by wheeled vehicles.
2. Where the head, in metres, h_1, exceeds 3,5 m this thickness is to be increased by the factor:
$\sqrt[3]{\dfrac{h_1}{3{,}5}}$</td></tr>
</table>

3.5 Vehicle ramps

3.5.1 The strength of ramps forming an integral part of the ship's structure, and of ramps used as watertight means of closing, is to be equivalent to the surrounding ship's structure. The strength of the ramps is also to be verified for vehicle loading and to comply with Pt 3, Ch 9,2.

3.5.2 Where hinges are provided for support of ramps, the ship's structure in way is to be suitably reinforced.

■ *Section 4*
Single bottom structure

4.1 General

4.1.1 The requirements of Ch 1,6 are to be applied together with the requirements of this Section. Additionally, scantlings for structural members of longitudinally framed single bottoms are given in Table 2.4.1. The scantlings of longitudinals are based on end connections in accordance with Pt 3, Ch 10,3.

4.2 Girders (longitudinal framing)

4.2.1 A centreline girder is generally required in ships with a breadth, B, of more than 6 m. Alternatively, side girders may be fitted under pillars supporting the deck structure, but generally adequate support for docking purposes is to be provided on the centreline. Girders are to have the same depth as transverses.

4.3 Transverses (longitudinal framing)

4.3.1 Transverses are to be fitted at a spacing not exceeding 2,5 m. Vertical stiffeners having a depth not less than 50 mm are to be fitted to the transverses at every fourth longitudinal. In between the transverses, brackets are to be fitted connecting the transverse side frames to the outer bottom longitudinal.

4.3.2 Where transverses support point loads, the required section modulus and shear area are to be verified by direct calculation. For permissible stresses, *see* Section 7.

■ *Section 5*
Double bottom structure

5.1 General

5.1.1 The requirements of Ch 1,7 are to be applied together with the requirements of this Section.

5.1.2 Where the tank top is to be used for the carriage of wheeled vehicles, the depth of the double bottom is to be at least 650 mm and the space is to be accessible. The minimum thickness of floors and inner bottom longitudinals is to be 7 mm and the inner bottom plating and bottom structure is also to comply with the requirements of Pt 3, Ch 9,2.

5.2 Floors

5.2.1 Where floors support point loads, with or without the addition of uniformly distributed loads, the required section modulus and shear area are to be verified by direct calculation. For permissible stresses, *see* Section 7.

Table 2.4.1 Longitudinally framed single bottom

Item	Parameter	Requirement
(1) Girders	Web and face plate thickness Width of face plate	$t = 0{,}01d_w + 3$ mm $b_f = 100$ mm
(2) Bottom transverses	Modulus	$Z = 7D_1 S\, l_e^2$ cm^3
(3) Bottom longitudinals	Modulus	$Z = (2 + 0{,}1L_1)\, D_1\, s\, l_e^2$ cm^3
Symbols		
$L, B, D, T, S, s, l_e, Z, I$ and t are as defined in 1.5.1 b_f = width of face plate, in mm d_w = web depth of floor or girder, in mm D_1 = D but need be taken not greater than T + 0,4 m L_1 = L but is to be not less than 40 m, nor more than 100 m		

■ *Section 6* Side shell structure

6.1 General

6.1.1 This Section covers the arrangements and requirements for a transversely or longitudinally framed side shell structure in single and double skin ships.

6.1.2 The scantlings of the side shell structural members in single skin ships are to comply with Table 2.6.1. The scantlings given in this Table are based on end connections in accordance with Pt 3, Ch 10,3. Where brackets having arm lengths differing from the standard are fitted, the modulus of the stiffening member is to be corrected in accordance with Pt 3, Ch 10,3.7.

6.1.3 The side shell structure for double skin ships is to comply with the requirements of Ch 1,11.

6.2 Web frames

6.2.1 Web frames forming a ring system with floors or bottom transverses and deck transverses, are to be fitted at a spacing not exceeding 8 m.

6.3 Frames

6.3.1 When the side frames are supported by an effective system of stringers and web frames, the Rule section modulus of side frames, ascertained ignoring the stringers, may be reduced by 30 per cent.

■ *Section 7* Direct calculation procedures

7.1 General

7.1.1 This Section contains guidance for direct calculations, information regarding maximum permissible stresses and minimum requirements for structural members included in the hull midship section modulus and for other structural members which do not form part of the hull midship section modulus.

7.1.2 Where direct calculation is adopted as an alternative to scantlings derived by Rule formulae, or for the assessment of scantlings of structural members not covered by the Rules, all data in support of the calculation, i.e. support conditions and loads, are to be submitted for approval together with the calculation.

7.2 Permissible stresses

7.2.1 In addition to the permissible stresses given in Pt 3, Ch 4,6 the following stress criteria are to be applied:

(a) For structural members included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in Table 2.7.1.

(b) For structural members not included in the hull section modulus the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in Table 2.7.2.

Table 2.6.1 Side shell structure (single skin ships)

Item	Parameter	Requirement
(1) Side frame	Modulus	$Z = 7 h_f s l_e^2$ cm^3
(2) Side longitudinals	Modulus	$Z = (4{,}6 + 0{,}0342 L_1) h_f s l_e^2$ cm^3
(3) Side transverses	Modulus	$Z = 10 h_f S l_e^2$ cm^3 *See* Note
(4) Stringers	Modulus	$Z = 6{,}6 h_f S l_e^2$ cm^3
(5) Webs supporting stringers and girders	Modulus	Z is to be determined from calculations using a stress of 98 N/mm^2 (10,0 kgf/mm^2) assuming fixed ends, in association with a head, h_f. *See* Note
Symbols		
L, S, s, l_e, Z and I are as defined in 1.5.1 h_f = the vertical distance, in metres, from the middle of the effective length of the stiffening member under consideration to the deck at side or to a line at T + 0,4 m, whichever is the lesser, but is to be taken as not less than 2,0 m L_1 = L but is to be not less than 40 m, nor more than 100 m		
NOTE The section modulus of side transverses or webs at top and bottom is to be not less than half the section modulus of the bottom and deck transverses in way.		

Table 2.7.1 Maximum permissible stresses in longitudinal continuous members, in N/mm^2 (kgf/mm^2)

Item	Local bending stress, σ_b	Combined bending stress, σ_c, *see* Note 1	Shear stress, τ	Equivalent stress, σ_e, *see* Note 2
Bottom girders Deck girders	108 (11,0)	177 (18,0)	83 (8,5)	188 (19,2)
Bottom longitudinals Inner bottom longitudinals Deck longitudinals Side shell longitudinals	137 (14,0)	177 (18,0)	83 (8,5)	188 (19,2)

NOTES
1. The combined stress σ_c is the sum of the stresses due to longitudinal bending and local loading.
2. The equivalent stress σ_e is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_c^2 + 3\tau^2}$

Table 2.7.2 Maximum permissible stresses in local members, in N/mm^2 (kgf/mm^2)

Item	Bending stress, σ_b	Shear stress, τ	Equivalent stress, σ_e, *see* Note
Floors, non-continuous bottom girders, non-continuous deck girders, deck transverses	124 (12,6)	83 (8,5)	177 (18,0)
Web frames	98 (10,0)	83 (8,5)	163 (16,6)
Frames, bottom transverse	113 (11,5)	83 (8,5)	172 (17,5)
Deck beams	137 (14,0)	83 (8,5)	186 (19,0)

NOTE
The equivalent stress σ_e is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$

7.3 Structural requirements

7.3.1 As a first approximation the structural components may be determined according to the requirements of the preceding Sections of this Chapter.

7.3.2 In addition to the maximum permissible stresses given in 7.2, the following minimum plating thickness requirements are to be complied with:

(a) The thickness of bottom plating and side shell plating amidships is to be not less than the thickness of shell plating at ends, *see* Pt 3, Ch 5,2.
(b) The thickness of bilge plating amidships is to be 2 mm more than the bottom plating in way.
(c) The minimum thickness of the deck plating is to be not less than the thickness of deck plating at ends, *see* Pt 3, Ch 5,2.
(d) Depending on the level of compressive stresses, additional buckling calculations may be required.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to ships which are generally being towed and/or pushed or carried alongside another ship and to self-propelled ships with machinery aft, intended for the carriage of non-perishable cargo on deck.

1.1.2 The structural requirements of this Chapter are intended to cover the midship region (0,5*L*), as defined in Pt 3, Ch 3,2.2 for ships having a length not exceeding 125 m, a ratio of length to depth not exceeding 35 and a ratio of breadth to depth not exceeding seven.

1.1.3 Arrangements and scantlings forward and aft of the midship region are to comply with Pt 3, Ch 5 and Ch 6 so far as applicable, the remaining requirements of Part 3 are also to be complied with as appropriate to the intended arrangements.

1.1.4 The arrangements are to be as required in Chapter 1, as far as applicable, or as specified otherwise in this Chapter.

1.2 Structural configuration

1.2.1 This Chapter provides for a basic structural configuration of a single flush deck hull with only small access openings, and with single bottom and single skin side construction.

1.2.2 Longitudinal or transverse framing may be adopted, or a combination thereof. For ships over 50 m in length, it is recommended that a longitudinal framing system in bottom and deck be used.

1.2.3 The number and disposition of transverse bulkheads are to be as required by Pt 3, Ch 7, but additional transverse bulkheads may have to be fitted to provide for sufficient transverse strength of the ship. It is recommended that longitudinal bulkheads be fitted to support the bottom and deck structure.

1.3 Class notation

1.3.1 Ships complying with the requirements of this Chapter will be eligible to be classed:

‘A1 I.W.W. pontoon’, or

‘A1 I.W.W. pontoon, self propelled’.

1.3.2 The Regulations for classification and assignment of class notations are given in Pt 1, Ch 2, to which reference should be made on the survey request form.

1.3.3 Where a ship has been specially designed, modified and/or arranged in accordance with the additional requirements for Zones 2 or 1, for service extension, for any special loading or discharging sequence or for navigation in ice, the appropriate class notation will be assigned.

1.4 Information required

1.4.1 For information required, *see* Pt 3, Ch 1,5. In addition, the following are to be supplied:

(a) Details of cargo loading on deck, *see* Pt 3, Ch 3,4.
(b) The maximum pressure head in service on tanks.
(c) Details of tanks which will be solely used for water ballast.
(d) Details of wheeled vehicles, when used for loading/unloading of the cargo.

1.5 Symbols and definitions

1.5.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D and *T* are as defined in Pt 3, Ch 1,6.1

l = overall length of stiffening member, in metres, *see* Pt 3, Ch 3,2.2
l_e = effective length of stiffening member, in metres, *see* Pt 3, Ch 3,3.3
s = spacing of secondary stiffeners, i.e. frames, beams, or stiffeners, in metres
t = thickness of plating, in mm
I = inertia of stiffening member, in cm^4, *see* Pt 3, Ch 3,3.2
S = spacing, or mean spacing, of primary members, i.e. girders, transverses, webs, etc., in metres
Z = section modulus of stiffening member, in cm^3, *see* Pt 3, Ch 3,3.2.

■ *Section 2* Longitudinal strength

2.1 General

2.1.1 The longitudinal strength of the ship is to comply with the requirements of Pt 3, Ch 4 and, for this purpose, a pontoon is to be considered as a Category ‘O’ ship.

2.1.2 The ratio of cargo compartment length, *L,* is to be taken as 0,73.

■ *Section 3*
Hull envelope plating

3.1 General

3.1.1 The requirements of Ch 1,5 are to be applied together with the requirements of this Section. The thickness of hull envelope plating amidships is to be not less than required in Table 3.3.1, but for ships over 40 m in length, the thickness of the bottom plating and deck plating may require to be increased to obtain the midship section modulus required in Pt 3, Ch 4.

3.2 Deck plating

3.2.1 Where openings are made in the deck plating for access, the deck plating in way is, generally, to be increased in thickness to compensate for the material cut out. However, no compensation need be fitted if the loss of sectional area has already been taken into consideration when calculating the actual midship hull section modulus.

3.2.2 Circular openings in deck of a diameter of 150 mm or less need not be compensated, provided they are situated well clear of other openings and the area cut out transversely over the deck does not exceed three per cent of the total area.

3.2.3 Plate panels, in which openings are cut are, where necessary, to be adequately stiffened against compression.

3.2.4 Areas of the deck used by wheeled vehicles are also to comply with the requirements of Pt 3, Ch 9,2.

Table 3.3.1 Hull envelope plating (*see continuation*)

Item and parameter	Required minimum scantlings	
(1) Plate keel Breadth Thickness	$0,1B$ m but not less than 0,75 m As bottom plating t_b When there is a rise of floor, the thickness is to be increased by 1 mm	
(2) Bottom plating Thickness	Longitudinal framing	Transverse framing
	The greater of: $t_b = (5,6 + 0,054L)\sqrt{s}$ mm $t_b = 10s$ mm	The greater of: $t_b = (5,6 + 0,054L)\sqrt{s}$ mm $t_b = 10s$ mm
	but for ships with a length, L, exceeding 40 m, t_b is to be not less than:	
	The greater of: $t_b = 0,076 \dfrac{M}{B \times D} - \dfrac{a_1}{10B}$ mm $t_b = 2,3 \sqrt[3]{\dfrac{MH \times s^2}{B \times D}}$ mm	The greater of: $t_b = 0,076 \dfrac{M}{B \times D}$ mm $t_b = 3,85 \sqrt[3]{\dfrac{MH \times s^2}{B \times D \times C_1}}$ mm
(3) Bilge plating Thickness	Longitudinal and transverse framing $t = t_b + 2$ mm	
(4) Bilge chine bars (a) Round bars Diameter (b) Square bars Width (c) Angle bars Flange thickness	$3t_b$ mm but not less than 30 mm $3t_b$ mm but not less than 30 mm $t = 2t_b$ mm	
(5) Side shell plating Thickness	The greater of: $t = (5,6 + 0,054L)\sqrt{s}$ mm $t = 10s$ mm	
(6) Sheerstrake Width Thickness	$0,1D$ m but not less than 0,2 m $t = t_d$ plus 5 mm *See* Note 1	
(7) Deck plating Thickness	Longitudinal framing	Transverse framing
	The greater of: $t = (5,6 + 0,039L)\sqrt{s}$ mm $t = 10s$ mm $t = 6$ mm *See* Note 2	The greater of: $t = (5,6 + 0,039L)\sqrt{s}$ mm $t = 10s$ mm $t = 6$ mm *See* Note 2
	but for ships with a length, L, exceeding 40 m, t is to be not less than:	
	The greater of: $t = 0,076 \dfrac{M}{B \times D} - \dfrac{a_1}{10B}$ mm $t = 2,3 \sqrt[3]{\dfrac{MH \times s^2}{B \times D}}$ mm	The greater of: $t = 0,076 \dfrac{M}{B \times D}$ mm $t = 3,85 \sqrt[3]{\dfrac{MH \times s^2}{B \times D \times C_1}}$ mm

Table 3.3.1 **Hull envelope plating** (*conclusion*)

Symbols
L, *B*, *D*, *T*, *S*, *s* and *t* are as defined in 1.5.1 a_1 = total area of bottom or deck longitudinals, as applicable, in cm^2 t_b = thickness of bottom plating, in mm t_d = thickness of deck plating connected to the sheerstrake, in mm $C_1 = 1 + 3\left(\frac{s}{S}\right)^2$, where $\frac{s}{S}$ is the ratio of the unstiffened plate panel under consideration *M* = the greater of *MS* and *MH* *MH* = maximum design hogging bending moment, in tm, *see* Pt 3, Ch 4 *MS* = maximum design sagging bending moment, in tm, *see* Pt 3, Ch 4
NOTES 1. Where a substantial welded steel rubbing bar is fitted, the sheerstrake may be of the same thickness as the side shell in way. 2. Where the head on deck in metres, h_1, as defined in Pt 3, Ch 3,4 exceeds 3,5 m, this thickness is to be increased by the factor $\sqrt[3]{\frac{h_1}{3{,}5}}$

■ *Section 4*
Hull envelope framing (longitudinal or transverse framing)

4.1 General

4.1.1 The requirements of Ch 1,11 are to be applied together with the requirements of this Section. The scantlings of the hull structural members are to comply with Table 3.4.1.

4.1.2 Scantlings given in Table 3.4.1 are based on end connections in accordance with Pt 3, Ch 10,3. Where brackets having arm lengths differing from the standard are fitted, the modulus of the stiffening member is to be corrected inaccordance with Pt 3, Ch 10,3.7.

4.2 Longitudinal framing system

4.2.1 A centreline girder is generally required in ships with a breadth, *B*, of more than 6 m. Alternatively, side girders may be fitted under pillars supporting the deck structure, but generally adequate support for docking purposes is to be provided on the centreline. Girders are to have the same depth as transverses.

4.2.2 Longitudinal stiffening members are to be supported by transverses arranged to form ring systems. Their spacing is not to exceed 3,5 m.

4.2.3 The depth of transverses is generally to be not less than twice the depth of the slot for the longitudinals.

4.2.4 Transverses fitted on the inboard face of longitudinals are to comply with the requirements of Pt 3, Ch 3,3 and associated Fig. 3.3.4 in Pt 3, Ch 3.

4.2.5 Longitudinals are generally to be carried through transverse bulkheads. If they stop at transverse bulkheads, brackets are to be fitted inter-connecting the longitudinals. *See also* Pt 3, Ch 10,3.3.1(c).

4.2.6 Scallops in longitudinals may not be fitted in way of end connections, crossings with transverses or tripping brackets.

4.3 Transverse framing system

4.3.1 Floors, frames and deck beams are to be fitted at every frame. Girders may be fitted to reduce the unsupported span of floors and deck beams.

4.3.2 When side frames are supported by an effective system of stringers and web frames, the Rule section modulus of the frames (ignoring the stringers) may be reduced by 30 per cent.

4.4 Combination system

4.4.1 Where a combination framing system is adopted (shell transverse and bottom and deck longitudinal framing) a transverse ring system as indicated in 4.2.2 is to be fitted.

4.4.2 Brackets at the top and bottom of side frames are to extend to the adjacent deck or bottom longitudinal to which they are to be connected.

4.5 Deck supporting structure

4.5.1 Deck girders and transverses may be fitted in conjunction with load-bearing bulkheads or pillars, for support of deck beams and deck longitudinals.

Table 3.4.1 Hull envelope framing (*see continuation*)

Item	Parameter	Requirements
(1) Floors	Modulus Web depth Web thickness	$Z = 6{,}6 \times D_1 \times s \times l_e^2$ cm^3 $d_w \geq 30B$ mm $t = 0{,}01 d_w + 2$ mm
(2) Bottom longitudinals	Modulus Inertia	$Z = (2 + 0{,}1L_1) \times D_1 \times s \times l_e^2$ cm^3 $I = 2{,}3 \times l_e \times Z$ cm^4
(3) Bottom transverses	Modulus	$Z = 7 \times D_1 \times S \times l_e^2$ cm^3
(4) Bottom centre girder	Web and face plate thickness Minimum flange width	$t = 0{,}01 d_w + 3$ mm $b_f = 100$ mm
(5) Bottom side girders	Scantlings	As centre girders
(6) Side frames	Modulus	$Z = 7 \times h_f \times s \times l_e^2$ cm^3 *See* Note 1
(7) Side longitudinals	Modulus	$Z = (4{,}6 + 0{,}0342L_1) \times h_f \times s \times l_e^2$ cm^3
(8) Side transverses	Modulus	$Z = 10 \times h_f \times S \times l_e^2$ cm^3 *See* Note 1
(9) Stringers	Modulus	$Z = 6{,}6 \times h_f \times S \times l_e^2$ cm^3
(10) Web supporting stringers and girders	Modulus	Z is to be determined from calculations using a stress of 98 N/mm^2 (10,0 kgf/mm^2), assuming fixed ends, in association with a head, h_f *See* Note 1
(11) Deck beams	Modulus	$Z = 4{,}3 \times h_1 \times s \times l_e^2 + 4$ cm^3
(12) Deck longitudinals	Modulus Inertia	$Z = (1{,}45 + 0{,}07L_1) \times h_1 \times s \times l_e^2$ cm^3 $I = 2{,}3 \times l_e \times Z$ cm^4
(13) Deck girders	Modulus Inertia	$Z = (1{,}35 + 0{,}085L_1) \times S \times h_1 \times l_e^2$ cm^3 $I = 2{,}3 \times l_e \times Z$ cm^4
(14) Deck transverses	Modulus	$Z = 4{,}75 \times h_1 \times S \times l_e^2$ cm^3
(15) Pillars	Cross-sectional area Minimum wall thickness of hollow pillars	$A_p = \dfrac{P}{1{,}26 - 4{,}2\sqrt{r}}$ cm^2 The greater of: (a) $t = 0{,}033 d_p$ mm for tubular pillars $t = 0{,}056 b$ mm for square pillars (b) $t = 5$ mm

Symbols

$L, B, D, T, S, s, l_e, Z, I$ and t are as defined in 1.5.1

b = breadth of side of a hollow square pillar, in mm
b_f = minimum flange width of the bottom centre girder or bottom side girders as applicable
d_p = mean diameter of tubular pillars, in mm
d_w = depth of web plate, in mm
h_f = the vertical distance, in metres, from the middle of the effective length of the stiffening member under consideration to the deck at side or to a line at T + 0,4 m, whichever is the lesser, but is to be taken as not less than 0,25D m
h_1 = head on deck, in metres, as defined in Pt 3, Ch 3,4, but is to be taken as not less than 1,5 m
l = overall length of pillar, in metres
r = least radius of gyration of pillar cross-section, in mm, and may be taken as:

$$r = 10\sqrt{\frac{I_p}{A_p}}$$

A_p = cross-sectional area of pillar, in cm^2
D_1 = D but need not be taken greater than T + 0,4 m
I_p = least moment of inertia of cross-section, in cm^4
L_1 = L but is to be not less than 40 m, nor more than 100 m
P = load supported by the pillar, in tonne-f

Table 3.4.1 Hull envelope framing (*conclusion*)

NOTES
1. The section modulus of side transverses and frames connecting deck and bottom transverses at top and bottom is to be not less than half the section modulus of the bottom and deck transverse whereto connected.
2. In case the scantlings of longitudinal members result in an appreciable excess in the hull midship section modulus as required by Pt 3, Ch 4 for the ship type concerned, a reduction in the modulus of the relevant members may be applied provided the permissible combined bending stress and the permissible local bending stress are not exceeded. For permissible stresses, *see* Section 5.

4.5.2 Effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Tripping brackets or equivalent are to be fitted to the transverse or girder web plates in way of the pillar. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

4.5.3 Areas of the deck used by wheeled vehicles are also to comply with the requirements of Pt 3, Ch 9,2.

4.5.4 The scantlings of the deck supporting structure forward and aft of the midship region are to be based on the actual deck loading but the head on deck, h_1, is to be taken as not less than 1,5 m.

4.6 Truss arrangements

4.6.1 Truss arrangements, comprising top and bottom girders or transverses in association with pillars and diagonal bracing, may be fitted to support the bottom and deck structure. The diagonal members are generally to have angles of inclination with the horizontal of 45° and a cross-sectional area of not less than 50 per cent of the adjacent pillar.

■ *Section 5*
Direct calculation procedures

5.1 General

5.1.1 This Section contains guidance for direct calculations, information regarding maximum permissible stresses and minimum requirements for structural members included in the hull midship section modulus and for other structural members which do not form part of the hull midship section modulus.

5.1.2 Where direct calculation is adopted as an alternative to scantlings derived by Rule formulae, or for the assessment of scantlings of structural members not covered by the Rules, all data in support of the calculation, i.e. support conditions and loads, are to be submitted for approval together with the calculation.

5.2 Permissible stresses

5.2.1 In addition to the permissible stresses given in Pt 3, Ch 4,6 the following stress criteria are to be applied:
(a) For structural members included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in Table 3.5.1.
(b) For structural members not included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in Table 3.5.2.

Table 3.5.1 Maximum permissible stresses in longitudinal continuous members, in N/mm² (kgf/mm²)

Item	Local bending stress, σ_b	Combined bending, stress, σ_c, *see* Note 1	Shear stress, τ	Equivalent stress, σ_e, *see* Note 2
Bottom girders Deck girders	108 (11,0)	177 (18,0)	83 (8,5)	188 (19,2)
Bottom longitudinals Inner bottom longitudinals Deck longitudinals Side shell longitudinals	137 (14,0)	177 (18,0)	83 (8,5)	188 (19,2)

NOTES
1. The combined stress, σ_c, is the sum of the stresses due to longitudinal bending and local loading.
2. The equivalent stress, σ_e, is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_c^2 + 3\tau^2}$

Table 3.5.2 Maximum permissible stresses in local members, in N/mm^2 (kgf/mm^2)

Item	Bending stress, σ_b	Shear stress, τ	Equivalent stress, σ_e, *see* Note
Floors, non-continuous bottom girders, non-continuous deck girders, deck transverses	124 (12,6)	83 (8,5)	177 (18,0)
Web frames	98 (10,0)	83 (8,5)	163 (16,6)
Frames, bottom transverses	113 (11,5)	83 (8,5)	172 (17,5)
Deck beams	137 (14,0)	83 (8,5)	186 (19,0)

NOTE
The equivalent stress, σ_e, is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_b{}^2 + 3\tau^2}$

5.3 Structural requirements

5.3.1 As a first approximation the structural components may be determined according to the requirements of the preceding Sections of this Chapter.

5.3.2 In addition to the maximum permissible stresses given in 5.2 the following minimum plating thickness requirements are to be complied with. The thickness of bottom plating and side shell plating amidships is to be not less than the thickness of shell plating at ends, *see* Pt 3, Ch 5,2. The thickness of the bilge plating amidships is to be 2 mm more than the bottom plating in way. The minimum thickness of the deck plating is to be not less than the thickness of deck plating at ends, *see* Pt 3, Ch 5,2. Depending on the level of compressive stresses, additional buckling calculations may be required.

Section 1
General

1.1 Application and definitions

1.1.1 This Chapter applies to propelled and non-propelled tankers of Type G, C and N intended for the carriage of dangerous liquids in bulk.

1.1.2 Most of the definitions hereunder have been derived from Part 1 of the ADN. Only the ADN definitions relevant to this Chapter have been included. A number of ADN definitions have been reworded. For a complete overview of all ADN definitions, reference is made to Part 1 of the ADN:

Accommodation means spaces intended for the use of persons normally living on board, including galleys, food stores, lavatories, washrooms, bathrooms, laundries, halls, alleyways, etc., but excluding the wheelhouse.

Cargo area means the whole of the following spaces (*see* Fig. 4.1.1);

Cargo area (additional part above deck) (when anti-explosion protection is required, comparable to zone 1) means the spaces not included in the main part of cargo area above deck comprising 1,00 m radius spherical segments centred over the ventilation openings of the cofferdams and the service spaces located in the cargo area part below the deck and 2,00 m spherical segments centred over the ventilation openings of the cargo tanks and the opening of the pump rooms;

Cargo area (main part above deck) (when anti-explosion protection is required – comparable to zone 1) means the space which is bounded:

- at the sides, by the shell plating extending upwards from the deck's sides;
- fore and aft, by planes inclined at 45° towards the cargo area, starting at the boundary of the cargo area part below deck;
- vertically, 3,00 m above the deck;

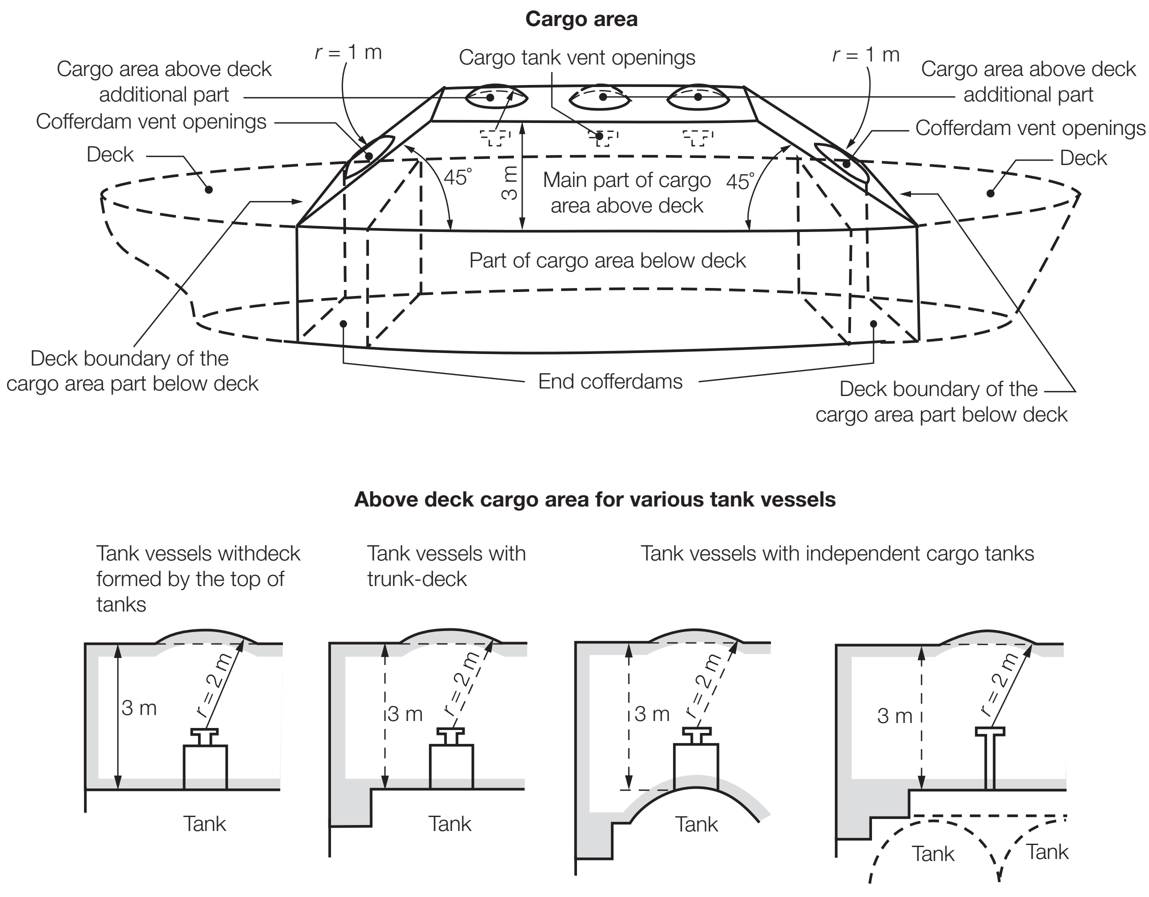


Fig. 4.1.1 Above deck cargo area for various tank vessels

Cargo area (part below deck) means the space between two vertical planes perpendicular to the centre-line plane of the vessel, which comprises cargo tanks, hold spaces, cofferdams, double-hull spaces and double bottoms; these planes normally coincide with the outer cofferdam bulkheads or hold end bulkheads. Their intersection line with the deck is referred to as the boundary of the cargo area part below deck;

Cargo tank (when anti-explosion protection is required, comparable to zone 0) means a tank intended for the carriage of dangerous or non-dangerous liquids. The cargo tank can either be integral with the hull structure of the ship or can consist of a separate tank independent from the ship's hull.

Cargo tank (open or closed type). The following basic types of cargo tanks can be discerned:

- 'Open type' cargo tanks are tanks in which the cargo is carried at atmospheric pressure by means of a ventilation system open to the air.
- 'Closed type' cargo tanks are tanks in which the cargo is shut-off from the open air during carriage and which are protected against overpressure and unacceptable vacuum.

Classification of zones (*see* IEC publication 79-10, EU directive 1999/92/EG):

- Zone 0: areas in which dangerous explosive atmospheres of gases, vapours or sprays exist permanently or during long periods;
- Zone 1: areas in which dangerous explosive atmospheres of gases, vapours or sprays are likely to occur occasionally;
- Zone 2: areas in which dangerous explosive atmospheres of gases, vapours or sprays are likely to occur rarely and, if so, for short periods only.

Cofferdam (when anti-explosion protection is required, comparable to zone 1) means an athwartship compartment which is bounded by watertight bulkheads and which can be inspected. The cofferdam shall extend over the whole area of the end bulkheads of the cargo tanks. The bulkhead not facing the cargo area shall extend from one side of the vessel to the other and from the bottom to the deck in one frame plane.

Flash-point means the lowest temperature of a liquid at which its vapours form a flammable mixture with air.

Identification number means the number for identifying a substance to which no UN number has been assigned or which cannot be classified under a collective entry with a UN number. These numbers have four figures beginning with 9.

Maximum working pressure means the maximum pressure occurring in a cargo tank or a residual cargo tank during operation. This pressure equals the opening pressure of high velocity vent valves.

Opening pressure means the pressure referred to in a list of substances at which the high velocity vent valves open.

Packing group means a group to which, for packing purposes, certain substances may be assigned in accordance with their degree of danger. The packing groups have the following meanings which are explained more fully in Part 2 of the ADNR/ADN:

- Packing group I: Substances presenting high danger;
- Packing group II: Substances presenting medium danger; and
- Packing group III: Substances presenting low danger.

Pressures. For tanks, all kinds of pressures (e.g. working pressure, opening pressure of the high velocity vent valves, test pressure) shall be expressed as gauge pressures in kPa (bar); the vapour pressure of substances, however, shall be expressed as an absolute pressure in kPa (bar).

Pressure tank means a tank designated and approved for a working pressure > 400 kPa (4 bar).

Tanker. A ship which has been specially designed and constructed for the carriage of liquids or gases in bulk.

Test pressure means the pressure at which a cargo tank, a residual cargo tank, a cofferdam or the loading and unloading pipes shall be tested prior to being brought into service for the first time and subsequently regularly within prescribed times.

UN number means the four-figure identification number of the substance or article taken from the United Nations Model Regulations.

1.2 International Regulations

1.2.1 The requirements of Lloyd's Register's (hereinafter referred to as LR) *Rules and Regulations for Classification of Inland Waterways Ships* (hereinafter referred to as the Rules for Inland Waterways Ships) intended for the carriage of dangerous liquids in bulk are based on the following international regulations:

- The United Nations' ADN regulations:
  The European Agreement concerning the International Carriage of Dangerous Goods by River;
- The ADNR regulations:
  The Regulations of the Central Rhine Commission (CCNR) concerning the transport of dangerous goods on the river Rhine (ADNR). See www.ccr-zkr.org.

1.2.2 The exemptions and derogations to the ADN and to the ADNR, as authorized by the CCNR, may also be taken into consideration.

1.2.3 The structural and other arrangements of tankers for the carriage of dangerous liquids in bulk, to be registered in, or to operate in countries with Regulations differing from ADN and ADNR will receive appropriate special consideration if required by the relevant Authorities and/or desired by the Owner.

1.2.4 At the time of publishing of these Rules, the ADNR was still in force as the governing regulations concerning the transport of dangerous goods on the river Rhine. In terms of it's validity on the river Rhine it is, however, foreseen that the ADNR will eventually be replaced by the ADN. Until then, subsequent references to the ADN in further paragraphs can also be considered as being references to the ADNR, as long as the ADNR has not been superseded by the ADN.

1.2.5 Although the contents of this Chapter take the ADN and ADNR Regulations into account, the issue of an ADN or ADNR Certificate on behalf of the Relevant Authorities requires full compliance with their Regulations.

1.2.6 Special attention is drawn to National and International technical and operational requirements of countries where the ship is registered or operating, which are outside classification as defined in the Rules and Regulations.

1.2.7 Electronic copies of the ADN can be downloaded from the site of the United Nations Economic Commission for Europe at

http://www.unece.org/trans/danger/adn-agree.html

1.2.8 Electronic copies of the ADNR can be downloaded from the site of the Central Commission for Navigation on the Rhine at www.ccr-zkr.org.

1.3 Dangerous liquids

1.3.1 Dangerous liquids are those liquids which according to the recommendations of the United Nations Committee of Experts on Transport of Dangerous Goods, and according to the provisions of the ADN belong to the following classes:

- Class 2 Gases; compressed, liquefied or dissolved under pressure.
- Class 3 Flammable liquids.
- Class 6.1 Poisonous (toxic) liquids.
- Class 8 Corrosive liquids.
- Class 9 Liquids having a potential hazard during transport not described in the above categories.

1.3.2 For further details of the Classification of dangerous gases and liquids, the assigment of UN numbers, and the designation of Packing groups in relation to the Classes of liquids, reference is made to Part 2 of the ADN.

1.3.3 All dangerous goods entries are listed in Table A of Chapter 3.2 of the ADN in the numerical order of their UN Number. This table contains relevant information on the goods listed, such as name, class, packing group(s), label(s) to be affixed, packing and carriage provisions.

1.3.4 An alphabetical list of the entries mentioned in 1.3.3 can be found in Chapter 3.2, Table B of the ADN.

1.3.5 Only those substances entered in Table C of Part 3 of the ADN are allowed to be carried in Tankers of Type G, C or N, *see also* 1.3.6.

1.3.6 The competent National Authority can, based on procedures by the United Nations Economic Commission for Europe, as laid down in the ADN, allow the transport of substances which have not yet been entered in Table C of Part 3 of the ADN. The resulting special permit as issued will be valid on all applicable rivers without any State or geographical limit, in compliance with the requirements as laid down in the special permit. The special permit will be valid for a maximum period of two years, which can be prolonged with a maximum period of one year after approval by the United Nations Economic Commission for Europe. For further procedures reference is made to Part 1, Section 1.5 of the ADN.

1.3.7 Attention is also drawn to the required compatibility of the cargo with the structural components of the ship, *see* 1.5.3.

1.4 Tanker types

1.4.1 For carriage of dangerous liquids of Classes 2, 3, 8 and 9, tankers are divided into the Types G, C and N.

Type G:

A Gas tanker, intended for the carriage of gases, compressed, liquefied or dissolved under pressure. The cargo tanks are to be of the closed type and to be independent from the hull structure. The ship shall comply with intact and damage stability criteria as laid down in the ADN.

Type C:

A Chemical tanker, intended for the carriage of liquids. The ship shall be of the flush-deck, double-hull type with double sides and double bottoms. The ship shall not be equipped with a trunk. The cargo tanks are to be of the closed type and may be integral with the vessel's hull structure or may consist of independent tanks installed in the hold spaces. The ship shall comply with intact and damage stability criteria as laid down in the ADN.

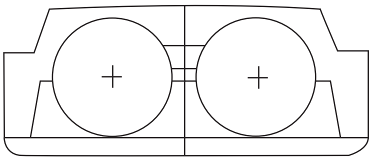
Type N:

A Tankship intended for the carriage of liquids. The following variations or combinations of variations can be applied in the construction of Type N tankers:

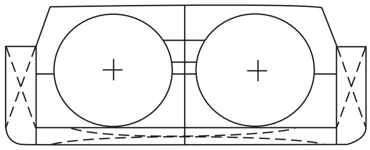
- Flush deck or trunk deck.
- Single hull or double hull.
- Integrated tanks or independent tanks.
- Closed or open tanks.
- Certain Type N ships of the double hull type should be compliant with ADN damage stability requirements.

The sketches shown in Fig. 4.1.2 are examples of possible hull configurations for Tankers of Types G, C and N respectively.

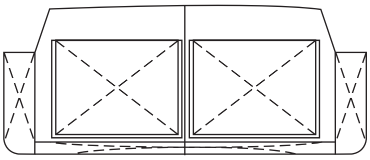
Type G:



Type G Condition of cargo tank 1,
Type of cargo tanks 1
(also by flush deck)

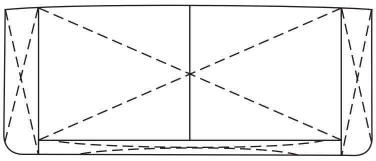


Type G Condition of cargo tank 1,
Type of cargo tanks 1
(also by flush deck)

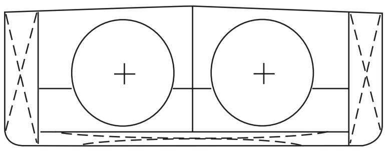


Type G Condition of cargo tank 2,
Type of cargo tank 1
(also by flush deck)

Type C:

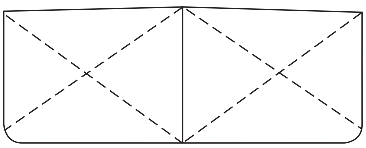


Type C Condition of cargo tank 2,
Type of cargo tank 2

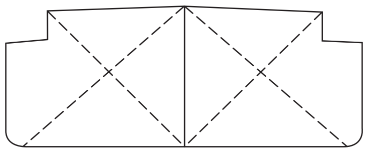


Type C Condition of cargo tank 1,
Type of cargo tank 2

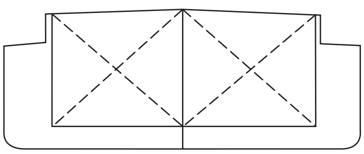
Type N:



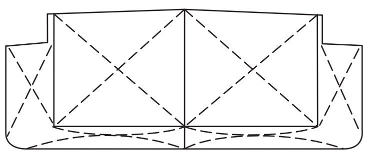
Type N Condition of cargo tank 2, 3 or 4
Type of cargo tank 2



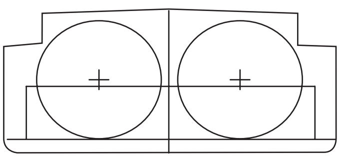
Type N Condition of cargo tank 2, 3 or 4
Type of cargo tank 2



Type N Condition of cargo tank 2, 3 or 4
Type of cargo tank 1
(also by flush deck)



Type N Condition of cargo tank 2, 3 or 4
Type of cargo tank 3
(also by flush deck)



Type N Condition of cargo tank 2, 3 or 4
Type of cargo tank 1
(also by flush deck)

Fig. 4.1.2 Examples of possible hull configurations for Tankers of the Types G, C and N

1.5 Designation of dangerous liquids to ship types

1.5.1 Dangerous liquids, carried in bulk are to be transported in tankers of the open or closed type having generally basic cross sections as in Fig. 4.1.2 depending on the class, classification code, packing group and properties of the liquid.

Dangerous liquids of Class 2

Gases; compressed, liquefied or dissolved under pressure are to be carried in Type G tankers.

Dangerous liquids of Class 3

Flammable liquids are generally to be carried in Type N tankers unless, depending on their properties and classification, a higher ship type is required. Liquids for which a certain ship type is requested may also be carried in a higher ship type.

Dangerous liquids of Class 6.1

Poisonous (toxic) liquids are to be carried in Chemical tankers of Type C. These liquids may also be carried in Type C or G tankers respectively.

Dangerous liquids of Class 8

Corrosive liquids are generally to be carried in Tankers of Type N, having, dependent on the properties of the liquids, open integral cargo tanks or open cargo tanks independent from the ship's structure. For some liquids, depending on their properties and classification, a higher ship type may be required. Corrosive liquids for which a certain ship type is requested may also be carried in a higher ship type.

Dangerous liquids of Class 9

Liquids having a potential hazard during transport not described in the above categories are to be carried in Tankers of Type N, having, dependent on the properties of the liquids, open integral cargo tanks or open cargo tanks independent from the ship's structure. These liquids may also be carried in tankers of Type N Closed, Type C and Type G respectively.

Non-dangerous liquids carried in bulk, are generally transported in an open type tanker having one of the basic cross-sections as for Type N tankers, *see also* Fig. 4.1.2.

1.5.2 All additional requirements for the particular substance as contained in Table C of Part 3 of the ADN are to be complied with by the particular Tanker before a substance is allowed to be carried. This also includes any additional requirements contained in column 20 of Table C. An approved list of defined cargoes is to be carried on board.

1.5.3 In addition to the requirements of 1.3.5 and 1.3.6, any substance is only allowed to be carried when the compatibility of the cargo with the material used in the construction of the cargo tanks of the ship has been taken into account and has been proven satisfactory.

1.5.4 After commissioning of the ship the owner is to ensure that all components used in the cargo system remain compatible with the products as mentioned in the *List of Defined Chemical Cargoes*.

1.6 Class notation

1.6.1 Ships complying with the applicable arrangements and requirements of this Chapter and of the appropriate ship type Chapter will be eligible to be classed '**A1 I.W.W.**' with further notations as indicated in the relevant ship type Chapter.

1.6.2 The Regulations for classification and assignment of class notations are given in Pt 1, Ch 2, to which reference should be made on the survey request form.

1.6.3 Where a ship has been specially designed, modified and/or arranged in accordance with the additional requirements for Zones 1 or 2, for service extension, for any special loading or discharging sequence or for navigation in ice, the appropriate class notation will be assigned.

1.7 Stability

1.7.1 The intact or damage stability of tankers of Type G, C or N is to be in accordance with recognized international stability requirements such as laid down in the ADNR or ADN. The stability calculations are to be approved by the competent National Authority. At the request of the Owner or builder and as delegated by the Competent National Authority LR can also issue a Statement of Compliance with specific national or international stability requirements.

■ *Section 2* Materials

2.1 Materials and grades of steel

2.1.1 Materials and grades of steel are to comply with the requirements of Chapter 3 of LR's *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) and as required by the individual ship type Chapter.

2.1.2 Where steel, or coated or lined steel, used in the construction of the cargo tanks is unsuitable for the carriage of the commodity and stainless steel is required, it is generally to be of the austenitic type which is suitable for the purpose. The stainless steel is to comply with the requirements of Ch 3,7 of the Rules for Materials. Other types of stainless steel will be specially considered.

2.1.3 Where stainless steel cargo tanks are arranged, only to preserve product purity, lower alloy stainless steels will be considered.

2.1.4 Mild steel fittings are not permitted in stainless steel cargo tanks.

2.1.5 The use of other materials will be specially considered, taking into account the properties of the commodities proposed to be carried.

2.2 Use of materials

2.2.1 The use of wood, aluminium alloys or plastic materials within the cargo area, as far as hull structural items are concerned, is prohibited, except for:

- chocking of cargo tanks which are independent of the vessel's hull and chocking of installations and equipment;
- masts and similar round timber;
- lids of boxes which are placed on the deck;
- supports and stops of any kind;
- Machinery items i.e. pumps, motors, etc.

The use of plastic materials or rubber within the cargo area is only permitted for:

- coating of cargo tanks and cargo lines;
- all kinds of gaskets (e.g. for domes or tank hatches);
- electric cables;
- hoses for loading and unloading;
- insulation of cargo tanks and cargo lines.

2.2.2 Wheelhouses may be constructed of aluminium, provided they are located abaft the aft cofferdams or forward of the forward cofferdam.

2.2.3 Means are to be provided to prevent spark formation within the cargo zone. The paint used in the cargo area shall not be liable to produce sparks in case of impact.

2.2.4 Toggles and their securing bolts (for instance, eyebolts) within the cargo zone for securing hatchcovers are not to be made of steel and are to be manufactured from either stainless steel, brass or an equivalent non-sparking material.

2.3 Protection of steelwork

2.3.1 All steelwork is to be protected according to Pt 3, Ch 2.

2.3.2 To avoid corrosive attack of the cargo tank structure by chemical cargoes, it is strongly recommended the structure be protected by suitable lining or coating.

2.3.3 The suitability of the lining or coating and its compatibility with the intended cargoes is the responsibility of the Builder and Owner. LR will, however, require the confirmation of the manufacturer that the lining or coating used to protect the cargo tank structure is compatible with the liquids mentioned in the *List of Defined Chemical Cargoes*.

2.3.4 Where stainless steel has been used for the construction of cargo tanks, brackish or salt water should not be carried in these tanks in order to avoid accelerated corrosion.

2.3.5 Where water ballast spaces incorporate both mild and stainless steel, special protective measures to avoid accelerated corrosion of the mild steel, such as the use of suitable coatings, are to be taken.

■ *Section 3* Ship arrangements

3.1 General

3.1.1 The requirements and provisions laid down in this Section are partly derived from the ADN. They form an integral part of LR's Rules for Inland Waterways Ships. Reference is made to the general terms described in 1.1. Further ADN requirements have been included in the Rules for machinery, electrical and control Engineering and Fire Requirements as applicable.

3.2 Hold spaces, cargo tanks and service spaces

3.2.1 In accordance with ADN requirements, the maximum permissible capacity of a cargo tank shall be determined in accordance with Table 4.3.1 where Loa x Boa x D is the product of the main dimensions of the ship, in metres, in accordance with the measurement certificate as issued by the competent National Authorities. For vessels with a trunk, D shall be replaced by D', where D' shall be obtained from the following formula:

$$D' = D + \left(\frac{h_t \times b_t}{Boa} \times \frac{l_t}{Loa}\right)$$

where

h_t = height of the trunk (distance between the trunk deck and main deck measured at the side of the trunk at $Loa/2$), in metres
b_t = breadth of the trunk, in metres
l_t = length of the trunk, in metres
Boa = the greatest overall breadth
Loa = the distance, in metres, from the forward side of the stem to the aftermost side of the stern

Attention is drawn to 3.6 concerning the special requirements for Type C tankers.

Table 4.3.1 Maximum permissible capacity of cargo tanks

Loa x *Boa* x *D*, in m^3	Maximum permissible capacity of a cargo tank (m^3)
< 600	*Loa* x *Boa* x *H* x 0,3
600 – 3750	180 + (*Loa* x *Boa* x *D* – 600) x 0,0635
> 3750	380

3.2.2 According to Table 4.3.1, the maximum tank capacity is limited to 380 m^3 irrespective of the size of the ship. The ADN, however, offers deviations of the prescribed tank capacities, provided the crash worthiness of the vessel is suitably increased. In this case the increased collision capabilities are to be proven by additional direct and statistical calculations. These calculations should be submitted to, and be approved by, the appropriate Classification Society.

3.2.3 In case of ships not falling under the competence of the ADN the maximum permissible capacity of a cargo tank will be specially considered.

3.2.4 Independent cargo tanks are to be provided with collision chocks and arrangements to prevent floating of the tank in case of ballasting or leakage into the cargo compartment space.

3.2.5 Underdeck service spaces located in the cargo area shall be easily accessible and shall permit the safe operation of all equipment contained therein by persons wearing protective clothing and safety devices. They shall be designed so as to allow injured or unconscious personnel to be removed from such spaces without difficulties by means of fixed equipment.

3.2.6 Cofferdams, double hull spaces, double bottoms, cargo tanks, hold spaces and other accessible spaces within the cargo area shall be arranged so that they can be completely inspected and cleaned in an appropriate way. The dimensions of openings, except for those of double hull spaces and double bottoms which do not have a common boundary with the cargo tanks, shall be sufficient to allow a person wearing breathing apparatus to enter or leave the space without difficulties. These openings shall have a minimum cross-sectional area of 0,36 m^2 and a minimum width of 0,50 m. They shall be designed so as to allow injured or unconscious personnel to be removed from the bottom of the space without difficulties by means of fixed equipment. In these spaces, the free distance for passage between the reinforcements shall not be less than 0,50 m. In double bottoms, this distance may be reduced to 0,45 m.

3.2.7 Cargo tanks may have circular access openings with a diameter of not less than 0,68 m.

3.2.8 Cargo tank openings shall be located on deck in the cargo area. Cargo tank openings with a cross-section of more than 0,10 m^2 shall be located not less than 0,50 m above deck.

3.2.9 All accommodation and service spaces are to be provided with natural or mechanical ventilation of sufficient capacity.

3.2.10 Ventilation ducts of under deck service spaces located in the cargo zone shall extend down to 50 mm above the bottom of the service space. The air inlets shall be located not less than 2,00 m above the deck, at a distance not less than 2,00 m from tank openings and 6,00 m from the openings of safety valves. The extension pipes, if necessary, may be of the hinged type. For ventilation of cargo pump-rooms, *see also* Pt 5, Ch 13,1.7.

3.2.11 Means are to be provided to prevent spark formation within the cargo zone.

3.2.12 Where a ventilation system ensuring an overpressure in accomodations wheelhouses or service spaces has been fitted and the electrical equipment in these spaces is not of the limited explosion risk type the windows are not to be capable of being opened.

3.2.13 Arrangements are to be made to contain minor spillage of the cargo.

3.2.14 Access to spaces in the cargo zone is to be direct from the upper deck.

3.2.15 Any opening in the deck in way of the cargo zone, such as for tank cleaning, sounding and taking cargo samples, is to be fitted with closing appliances which are oil and gastight at the appropriate test pressures. The number of openings is to be kept to a minimum. *See also* Pt 3, Ch 11,5 and Pt 3, Ch 11,6.

3.2.16 Fittings within cargo tanks, pump-rooms and cofferdams are to be effectively secured to the structure.

3.2.17 If below-deck cargo pump-rooms are fitted, easy access is to be provided and ladders should not be arranged vertically. Suitable handrails are to be provided.

3.2.18 Where the vessel is provided with hold spaces, the double bottoms within these spaces may be arranged as liquid oil fuel tanks, provided their depth is not less than 0,60 m.

3.2.19 For air and sounding pipes on cofferdams, *see* Pt 5, Ch 13,2.3.

3.3 Protection against the ingress of gases within accommodations and entrances

3.3.1 The vessel shall be designed so as to prevent gases from penetrating into the accommodation and the service spaces. This requirement does not apply to ships of Type N Open.

3.3.2 Pumps, compressors and cargo piping shall be located in the cargo area. Cargo pumps and compressors situated on deck shall be located not less than 6,00 m from entrances to, or openings of, the accommodation and service spaces outside the cargo area. The above requirements do not apply to ships of Type N Open with the exemption of ships of Type N Open carrying corrosive liquids of Class 8.

3.3.3 The distance required by 3.3.2 may be reduced to 3,00 m if a transverse bulkhead complying with 3.3.4 is situated at the end of the cargo area. The openings shall be provided with doors.

3.3.4 The lower edges of door-openings in the sidewalls of superstructures and the coamings of access hatches to under-deck spaces shall have a height of not less than 0,50 m above the deck. This requirement need not be complied with if the wall of the superstructures facing the cargo area extends from one side of the ship to the other and has doors with sill heights of at least 0,50 m. The height of this wall shall be not less than 2,00 m. In this case, the lower edges of door-openings in the sidewalls of superstructures and of coamings of access hatches behind this wall shall have a height of at least 0,10 m. The sills of engine-room doors and the coamings of its access hatches shall, however, always have a height not less than 0,50 m. The above requirements do not apply to ships of Type N Open.

3.3.5 In the cargo zone, the lower edge of hatches and openings in sidewalls of houses or superstructures shall have a height of at least 0,50 m above the deck. This requirement does not apply to openings of sidetanks and double bottoms and to ships of Type N Open.

3.3.6 The engine rooms shall be accessible from the deck; the entrances shall not face the cargo area. Where the doors are not located in a recess whose depth is at least equal to the door width, the hinges shall face the cargo area. This last requirement does not apply to bilge and bunkerboats.

3.3.7 Entrances of engine rooms shall be at a distance of not less than 2,00 m from the cargo area.

3.3.8 Ventilation inlets of the engine room, and when the engines do not take in air directly from the engine room, air intakes of the engines, shall be located not less than 2,00 m from the cargo area.

3.3.9 Accommodation spaces and the wheelhouse shall be located outside the cargo area forward of the fore vertical plane or abaft the aft vertical plane bounding the part of cargo area below deck. Windows of the wheelhouse which are located not less than 1,00 m above the bottom of the wheelhouse may tilt forward.

3.3.10 Entrances to spaces and openings of superstructures shall not face the cargo area. Doors opening outward and not located in a recess the depth of which is at least equal to the width of the doors shall have their hinges face the cargo area. This last requirement does not apply to bilge and bunkerboats.

3.3.11 Entrances and windows of superstructures and accommodation spaces which can be opened as well as other openings of these spaces shall be located not less than 2,00 m from the cargo area. Wheelhouse doors and windows shall not be located within 2,00 m from the cargo area, except where there is no direct connection between the wheelhouse and the accommodation. This requirement does not apply to bilge and bunkerboats.

3.3.12 Where a ventilation system ensuring an overpressure in accommodation, wheelhouses or service spaces has been fitted and the electrical equipment in these spaces is not of the limited explosion risk type, the windows are not to be capable of being opened.

3.3.13 Cofferdams shall be accessible through an access hatch having a coaming of at least 500 mm. If the cofferdam is integral with the double hull side tanks it may also be accessed through the sidetank.

3.4 Miscellaneous

3.4.1 The air pipes of all oil fuel tanks shall be led to 0,50 m above the open deck. The outlets of funnels shall be located not less than 2,00 m from the cargo area. Arrangements shall be provided to prevent the escape of sparks and the entry of water.

3.4.2 Where it is intended to carry cargoes which react hazardously with one another, they are to be separated by cofferdams, pump-rooms, void spaces, other cargo tanks or slop tanks which separate the two cargo tanks completely. In addition, there is to be corresponding segregation of the pumping and piping systems and tank vent systems.

3.5 Special requirements for Type G tankers

3.5.1 The ratio of the cargo tank length over the diameter is not to exceed seven.

3.5.2 In the cargo area, the hull shall be designed as follows:

(a) As a double-hull and double-bottom vessel. The internal distance between the sideplatings of the vessel and the longitudinal bulkheads shall not be less than 0,80 m, the height of the double bottom shall be not less than 0,60 m, the cargo tanks shall be supported by saddles extending between the tanks to not less than 20° below the horizontal centreline of the cargo tanks. Refrigerated cargo tanks shall be installed only in hold spaces bounded by double-hull spaces and double-bottom;
or
As a single hull vessel whereby the sideshell has been stiffened by stringers fitted over the full depth of the ship at a maximum spacing of 0,60 m, supported by web frames at a maximum spacing of 2,00 m. The side stringers and the web frames shall have a height of not less than 10 per cent of the depth, with a minimum of 0,30 m. The side stringers and web frames shall be fitted with flatbars made of flat steel and having a crosssection of not less that 7,5 cm^2 and 15 cm^2, respectively;
The distance between the sideplating of the vessel and the cargo tanks shall not be less than 0,80 m. The distance between the bottom of the vessel and the cargo tanks shall not be less than 0,60 m. The distance between the bottom of the vessel and the suction well shall not be less than 0,50 m.
The distance between the suction well of the cargo tanks and the bottom structure shall not be less than 0,10 m.
or
A different design of the hull in the cargo area can also be considered, provided proof can be supplied by means of direct calculations that in the event of a lateral collision with another vessel having a straight bow, an energy of 22 MJ can be absorbed without any rupture of the cargo tanks and the piping leading to the cargo tanks.
The cargo tanks shall be supported by stools extending at least to a level of 10° below the horizontal centreline of the tanks.

(b) The cargo tanks shall be fixed in such a way that they cannot float.

(c) The capacity of a suction well shall be limited to 0,10 m^3. For pressure cargo tanks, however, the capacity of a suction well may amount to 0,20 m^3.

(d) Profiles or struts connecting structural members of the sideshell with structural members on the longitudinal bulkhead are prohibited.

(e) Profiles or struts connecting structural members of the bottom shell with structural members on the inner bottom are prohibited.

3.5.3 Hold spaces shall comply with the following:

(a) The hold spaces shall be separated from the accommodation and service spaces outside the cargo area below deck by bulkheads provided with a Class A-60 fire protection insulation according to SOLAS Chapter II-2, Regulation 3. A space of not less than 0,20 m shall be provided between the cargo tanks and the end bulkheads of the hold spaces. Where the cargo tanks have plane end bulkheads, this space shall be not less than 0,50 m.

(b) The hold spaces and cargo tanks shall be capable of being inspected.

(c) All spaces in the cargo area shall be capable of being ventilated. Means for checking their gas-free condition shall be provided.

3.5.4 Service spaces below deck shall comply with the following:

(a) A space in the cargo area below deck may be arranged as a service space, provided that the bulkhead bounding the service space extends vertically to the bottom and the bulkhead not facing the cargo area extends from one side of the vessel to the other in one frame plane. This service space shall only be accessible from the deck.

(b) The service space shall be watertight with the exception of its access hatches and ventilation inlets.

3.6 Special requirements for Type C tankers

3.6.1 In the cargo area (except in way of the cofferdams) the vessel shall be designed as a flush-deck double-hull vessel, with double-hull spaces and double bottoms, but without a trunk. Cargo tanks independent of the vessel's hull as well as refrigerated cargo tanks may only be installed in a hold space which is bounded by double-hull spaces and double bottoms in accordance with 3.6.5. The cargo tanks shall not extend beyond the deck.

3.6.2 If sloptanks or tanks for residual cargo are fitted, their capacity is not to exceed 30 m^3.

3.6.3 Where independent cargo tanks are installed in the cargo space, a space of not less than 0,50 m shall be provided between such tanks and the end bulkheads of the cargo space. In this case an insulated end bulkhead meeting at least the definition for Class 'A-60' according to SOLAS 74, Chapter II-2, Regulation 3, shall be deemed equivalent to a cofferdam. For pressure cargo tanks, the distance of 0,50 m may be reduced to 0,20 m.

3.6.4 A cofferdam, the centre part of a cofferdam or another space below deck in the cargo area may be arranged as a service space, provided the bulkheads bounding the service space extend vertically to the bottom. This service space shall only be accessible from the deck. The service space shall be watertight with the exception of its access hatches and ventilation openings.

3.6.5 For double hull ships whereby the cargo tanks are integrated in the ship's structure, the distance between the side shell and the longitudinal cargo tank bulkhead shall be not less than 1,00 m. This distance may be reduced to 0,80 m, provided the following reinforcements are provided:

(a) 25 per cent increase in the thickness of the deck stringer plate;

(b) 15 per cent increase in the sideshell plating thickness;

(c) Arrangement of a longitudinal framing system at the vessel's side, where the depth of the longitudinals shall be not less than 0,15 m and the longitudinals shall have a face plate cross-sectional area of at least 7,0 cm^2.

(d) Stringers or longitudinals are to be supported by web frames spaced not more than 1,80 m apart. This distance may be increased if the longitudinals are strengthened accordingly.

When a vessel is built according to the transverse framing system, an additional stringer system shall be arranged. The distance between the stringers shall not exceed 0,80 m and their depth shall not be less than 0,15 m, provided they are completely welded to the frames. The cross-sectional area of the facebar or faceplate shall not be less than 7,0 cm^2. The mean depth of the double bottoms shall not be less than 0,70 m. At no location however, shall the depth be less than 0,60 m. The depth below the suction wells should not be less than 0,50 m.

3.6.6 Special attention is drawn to the additional ADN requirements of Part 9 Section 9.4 whereby the width of the double hull can be varied in relation to additional strengthenings and deviations from the maximum tank capacity as prescribed by the ADN. Alternative arrangements will be specially considered and should be backed-up by additional direct and statistical calculations as required by the ADN. These calculations should be submitted for approval.

3.6.7 When a vessel is built with independent or refrigerated cargo tanks, the width of the side tanks and the depth of the double bottom should not be less than 0,80 and 0,60 m respectively.

3.6.8 Profiles or struts connecting structural members of the sideshell with structural members on the longitudinal bulkhead are not allowed.

3.6.9 Profiles or struts connecting structural members of the bottom shell with structural members on the bottom of the cargo tank are not allowed.

3.6.10 When the vessel is provided with pressure cargo tanks, these tanks shall be designed for a working pressure of 400 kPa (4 bar).

3.6.11 For vessels with a length of not more than 50,00 m, the length of a cargo tank shall not exceed 10 m. For vessels with a length of more than 50,00 m, the length of a cargo tank shall not exceed 0,20*L*. This provision does not apply to vessels with independent built-in cylindrical tanks having a length to diameter ratio = 7.

3.6.12 The capacity of a suction well shall not exceed 0,10 m^3.

3.6.13 The cargo tanks shall be separated from the accommodation, engine room and service spaces below deck outside of the cargo area, or from the ship's end in the absence of such spaces, by cofferdams of at least 0,60 m in width.

3.6.14 The test pressure for the cargo tanks and residual cargo tanks shall not be less than 1,3 times the design pressure. The test pressure for the cofferdams and open cargo tanks shall not be less than 10 kPa (0,10 bar) gauge pressure. The testing of cargo tanks and cofferdams is to be in accordance with Pt 3, Ch 1,7.3.

3.6.15 Where fitted, the capacity of slop tanks or residual cargo tanks is not to exceed 30 m^3. For further requirements regarding these tanks, *see* Pt 5, Ch 13,3.10.

3.7 Special requirements for Type N tankers

3.7.1 On double hull ships with integrated cargo tanks or independent cargo tanks, the distance between the side shell and the cargo tank bulkhead is to be at least 0,60 m. The distance between the bottom of the ship and the cargo tank bottom is to be at least 0,50 m. This height may be reduced to 0,40 m in way of the pump suctions. The vertical distance between the pump suction of a cargo tank and the bottom structure is to be at least 0,10 m. Where a vessel is constructed with hold spaces containing cargo tanks which are independent of the structure of the vessel, the double hull space is to comply with the above. If the minimum required dimensions of openings for inspection of the cargo tank as per 3.2.6 are not feasible, it shall be possible to remove the cargo tanks easily for inspection.

3.7.2 When the vessel is provided with pressure cargo tanks, these tanks shall be designed for a working pressure of 400 kPa (4 bar).

3.7.3 For vessels with a length of not more than 50,00 m, the length of a cargo tank shall not exceed 10 m. For vessels with a length of more than 50,00 m, the length of a cargo tank shall not exceed 0,20*L*. This provision does not apply to vessels with independent built-in cylindrical tanks having a length to diameter ratio = 7.

3.7.4 The cargo tanks shall be separated from the accommodation, engine room and service spaces below deck outside of the cargo area, or from the ship's end in the absence of such spaces, by cofferdams of at least 0,60 m in width.

3.7.5 Where independent cargo tanks are installed in the cargo space, a space of not less than 0,50 m shall be provided between such tanks and the end bulkheads of the cargo space. In this case an insulated end bulkhead meeting at least the definition for Class 'A-60' according to SOLAS 74, Chapter II-2, Regulation 3, shall be deemed equivalent to a cofferdam. For pressure cargo tanks, the distance of 0,50 m may be reduced to 0,20 m.

3.7.6 A cofferdam, the centre part of a cofferdam or another space below deck in the cargo area may be arranged as a service space, provided the bulkheads bounding the service space extend vertically to the bottom. This service space shall only be accessible from the deck. The service space shall be watertight with the exception of its access hatches and ventilation openings.

3.7.7 Cargo tank openings shall be fitted with gastight closures closing devices capable of withstanding the test pressure in accordance with Pt 3, Ch 1.

3.7.8 The test pressure for the cargo tanks and residual cargo tanks shall not be less than 1,3 times the design pressure. The test pressure for the cofferdams and open cargo tanks shall not be less than 10 kPa (0,10 bar) gauge pressure. The testing of cargo tanks and cofferdams is to be in accordance with Pt 3, Ch 1,7.3.

3.7.9 Where fitted, the capacity of slop tanks or residual cargo tanks is not to exceed 30 m^3. For further requirements regarding these tanks, *see* Pt 5, Ch 13,3.10.

3.7.10 Any underdeck service space located in the cargo zone is to be provided with mechanical ventilation. The capacity is to be at least 20 air changes per hour. The ventilation exhaust ducts shall extend down to 50 mm above the bottom of the service space. The air inlets shall be located not less than 2,00 m above the deck, at a distance not less that 2,00 m from tank openings and 6,00 m from the openings of safety valves. The extension pipes, if necessary, may be of the hinged type.

3.7.11 Internal combustion engines for the vessel's propulsion as well as internal combustion engines for auxiliary machinery shall be located outside the cargo area.

■ *Section 4*
Carriage of dangerous cargoes

4.1 General

4.1.1 For general requirements, *see* 1.3 and 1.5. Attention is also drawn to the specific ship type requirements in Section 3.

4.1.2 With the exception of water reactivity, reactivity with the environment is not covered within the ADN. Self-reactivity is also excluded since in that case the cargoes concerned will be required to be inerted, inhibited or stabilized as indicated in Table C of the ADN. Interreactivity of cargoes or groups of cargoes has not been indicated in Table C of the ADN, the principal preventative arrangements being operational.

4.1.3 Where it is proposed to carry cargoes requiring temperature control for reasons of safe carriage, the temperature control arrangements are to be appropriate for the intended service and characteristics of the cargo, *see also* Pt 5, Ch 13,6 and 7.

4.1.4 Whilst many chlorinated hydrocarbon cargoes are not appreciably corrosive to such materials as mild steel, copper and its alloys and to aluminium when they are essentially dry, certain types of those cargoes may slowly generate traces of highly corrosive hydrochloric acid when in contact with water or moist air. Operational arrangements should, therefore, be such as to minimize the probability of contamination of chlorinated hydrocarbon cargoes with water and moisture.

4.1.5 Arrangements for preserving the quality of the cargo are the responsibility of the Owners.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to propelled and non-propelled tankers (barges) of Type G, intended for the carriage of dangerous liquids of Class 2 in bulk, in association with a List of Defined Chemical Cargoes and with class notations as indicated in 1.5. Although the ships will be primarily designed for the carriage of Class 2 liquids they could also be entitled to carry products of Classes 3, 6.1, 8 and 9 as permitted by the ADNR.

1.1.2 For further information on international regulations and the significance of tanker types, *see* Chapter 4.

1.1.3 For further information on dangerous liquids, *see* Section 2.

1.1.4 This Chapter mainly provides for requirements regarding structural aspects. For basic midship configurations and particular aspects and requirements regarding the design and arrangements of Type G tankers, *see* Chapter 4.

1.1.5 Alternative arrangements which are proposed as being equivalent to the Rules will receive individual consideration taking into account any relevant National Authority requirements.

1.1.6 The requirements of this Chapter take into account the ADNR Regulations of the Central Rhine Commission and the European Provisions concerning the International Carriage of Dangerous Goods by Inland Waterway (ADN) which assume heavy traffic on relatively narrow waterways through heavily populated areas.

1.1.7 Ships intended to be used on waterways with conditions different from those stated in 1.1.6 and where ADNR and ADN requirements are not applicable, will receive special consideration and the requirements may be modified to suit the actual conditions, *see also* Ch 4,1.2.

1.1.8 Although the contents of this Chapter and those of Chapter 4 take ADNR and ADN technical Regulations into account, the issue of an ADNR certificate by or on behalf of the relevant Authorities, requires full compliance with their Regulations which are to be consulted in all cases.

1.1.9 Where requested to do so by the Builder or Owner, LR will investigate compliance with the ADN Recommendations or ADNR Regulations indicated in 1.1.8 with a view to issuing a Statement of Compliance.

1.2 Ship arrangement

1.2.1 The ship is to be so arranged that the cargo is carried in pressure tanks independent from the ship's structure.

1.2.2 Self-propelled tankers are to have the machinery aft.

1.2.3 For ADNR and ADN related requirements such as the arrangement of cofferdams, double sides (as applicable), service spaces and accommodations, entrances and the protection against the ingress of gases and special requirements for Type G tankers, *see* Ch 4,3.

1.2.4 Individual cargo tanks are to be protected, as far as possible, against collision damage. The requirements are deemed to have been met if:

(a) The side shell is reinforced by side shell stringers supported by web frames over the cargo compartment length in accordance with Ch 4,3.5 or
(b) longitudinal bulkheads are fitted at least 800 mm from the side shell over the cargo compartment length.

For details, *see* 8.4 and Section 9.

1.2.5 The maximum tank capacity in accordance with the ADNR is to be determined in accordance with Ch 4,3.2. The ADNR however offers deviations of the prescribed tank capacities provided the crash worthiness of the vessel is suitably increased. This may be achieved by one, or a combination of the measures described in 1.3.5.

1.2.6 Arrangements and scantlings forward and aft of the midship region are to comply with Pt 3, Ch 5 and Pt 3, Ch 6 so far as applicable. The remaining requirements of Part 3 are also to be complied with as appropriate for the intended arrangements.

1.2.7 The number and disposition of transverse bulkheads are to be as required by Pt 3, Ch 7. Watertight transverse bulkheads without openings are to be fitted at the ends of the cargo compartment space.

1.3 Structural configuration

1.3.1 This Chapter provides for a basic structural configuration of a single flush deck or trunk deck hull with single or double bottom arrangement and single or double skin side construction in way of the cargo compartment space, the cross-section of the ship in way of the cargo compartment space in general being in accordance with Fig. 4.1.2, for Type G ships in Chapter 4.

1.3.2 The arrangement and requirements in the following Sections are for tankers having a length not exceeding 135 m, a ratio of length to depth not exceeding 30, a ratio of breadth to depth not exceeding five and the midship region as defined in Pt 3, Ch 3,2.1. When the limiting length of the ship or ratio of L/D or B/D are exceeded, the scantlings may have to be determined by direct calculation, *see* Pt 3, Ch 1,3.2 and Pt 3, Ch 4.

1.3.3 Transverse or longitudinal framing may be adopted. For ships having a length, *L*, of not less than 50 m, it is recommended longitudinal framing be applied to deck, trunk sides and trunk deck in association with either longitudinal framing in the bottom or transverse framing in the bottom with additional efficient longitudinal stiffening integral with the tank supports. Longitudinal framing adopted for deck and/or bottom in ships with longitudinal bulkheads according to 1.2.4(b) may be restricted to the areas between the longitudinal bulkheads.

1.3.4 For ADNR and ADN related structural requirements regarding double and single hull structures, the arrangements of cargo tank supports and miscellaneous structural requirements, *see* Ch 4,3.5.

1.3.5 In case the ship is provided with tanks exceeding the maximum tank capacity in accordance with the ADNR as described in 1.2.5 one, or a combination of the following measures need to be taken:

- Increase in sideshell and/or tank plating thicknesses, increase of stiffening arrangements or scantlings and spacings of primary members.
- Increase in the overall width of the double skin.
- Introduction of additional structural members.
- The appliance of special crashworthy structures.

In the above cases the increased collision capabilities are to be proven by additional direct and statistical calculations as required by the ADNR. These calculations should be submitted to, and be approved by the Society.

1.4 Class notation

1.4.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2,2.

1.4.2 Ships complying with the applicable requirements of this Chapter and other relevant Rule requirements will be eligible to be classed:

‘A1 I.W.W. Tanker Type G’

or

‘A1 I.W.W. Barge Type G’

together with the appropriate design specific gravity and in association with a List of Defined Chemical Cargoes, e.g.: ‘A1 I.W.W. Tanker Type G’ p.v. +400 kPa, S.G. 1.00 in association with a List of Defined Cargoes.

1.5 List of Defined Cargoes

1.5.1 The List of Defined Cargoes for the carriage for which the ship has been approved will be attached to the Classification Certificate.

1.5.2 Only those cargoes which are included in the List of Defined Cargoes may be carried.

1.5.3 The List of Defined Cargoes will be issued by the Society and will be based on Table C of Part 3 of the ADNR. Parameters will include the tanker type, cargo tank design and cargo tank type as well as the characteristics of all relevant equipment fitted in the cargo zone. All relevant parameters of Table C will be used as a basis for the list, including any relevant additional requirements contained in column 20. Attention is also drawn to Ch 4,1.5 in respect of material compatability.

1.6 Additional notations

1.6.1 Additional notations may be assigned for the following features:

(a) Tanks constructed of corrosion resistant materials, e.g. stainless steel ‘CR (s.stl)', or lined with corrosion resistant linings, e.g. rubber lining ‘CR (r.l)'.

(b) Minimum cargo temperature in °C for which the cargo tanks have been approved.

(c) Ambient design temperatures (when the carrier is suitable for continuous service in high and/or low temperature climatic conditions).

1.7 Materials

1.7.1 For materials and grades of steel, the use of materials and protection of steelwork reference is made to Ch 4,2. The materials and grades of steel used in the construction of the cargo pressure tanks are to comply with the requirements of Pt 5, Ch 9, taking into account the minimum temperature and maximum pressure of the cargo, also the maximum temperature if heating arrangements are fitted.

1.8 Stainless steel

1.8.1 The material is to comply with the requirements of Ch 8,2 and Ch 3,7 of Lloyd’s Register’s *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Other types of stainless steel will be specially considered.

1.8.2 Where the specified minimum yield stress or 0,5 per cent proof stress at the operating steel temperature is less than 235 N/mm^2 (24 kgf/mm^2), scantlings will be specially considered.

1.9 Information required

1.9.1 For the information required to be submitted, *see* Pt 3, Ch 1,5. In addition, the following are to be supplied:

(a) The design pressure of the cargo tanks.
(b) The proposed design cargo relative density (specific gravity).
(c) Details of corrosion protection of cargo tanks, ballast spaces and void spaces where applicable.
(d) Details of insulation on cargo tanks (if applicable).
(e) Details of materials of cargo tanks.
(f) Design loading sequence including data on non-uniform loading conditions that may be applicable.
(g) Particulars of filling, discharging, venting, relieving and inerting arrangements so far as applicable. Where filling, or discharging is carried out by vapour pressure, inert gas pressure or similar, the maximum pressure should be given.
(h) Details of temperature control arrangements if required or proposed to be installed.
(j) Details of tanks or spaces in the ship which will be used for carrying ballast water.
(k) The flag of the vessel and the country issuing statutory certificates.
(l) Any other relevant information that may influence the design of the ship or the proceedings during the approval process.

1.10 Symbols and definitions

1.10.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D and T are as defined in Pt 3, Ch 1,6.1

l_e = effective length of stiffening member, in metres, *see* Pt 3, Ch 3,3.3

s = spacing of secondary stiffeners, i.e. frames, beams, or stiffeners, in metres

t = thickness of plating, in mm

I = inertia of stiffening member, in cm^4, *see* Pt 3, Ch 3,3.2

S = spacing, or mean spacing, of primary members, i.e. girders, transverses, webs etc., in metres

Z = section modulus of stiffening member, in cm^3, *see* Pt 3, Ch 3,3.2.

■ *Section 2* Cargo characteristics and requirements for carriage

2.1 General

2.1.1 For general information on dangerous liquids and general requirements, *see* Ch 4,1.3, 1.4 and 1.5.

2.2 Filling limits for cargo tanks

2.2.1 In service areas which are considered to have a temperate climate the maximum volume to which a cargo tank for the carriage of liquefied gases of Class 2 may be filled is not to exceed 91 per cent of the volume of the total capacity of the cargo tank.

2.2.2 When the climatic conditions in the actual service area differ considerably from those indicated in 2.2.1, the maximum volume to which the tanks may be loaded will be specially considered.

2.2.3 For Class 3, 6.1, 8 and 9 products, higher filling rates in accordance with Table C of Part 3 of the ADNR are allowed.

■ *Section 3* Cargo pressure tanks independent of the ship's structure

3.1 General

3.1.1 Cargo tanks are to be constructed as pressure vessels according to the requirements of Pt 5, Ch 9. Proposals for non-cylindrical types of cargo tanks, complying with the requirements of 1.2.2 and 1.2.3, will receive special consideration.

3.1.2 The cargo tanks are to be placed below the continuous upper deck or trunk and are to be provided with domes, which are to be carried through the respective deck to a height of at least 0,5 m above the deck. The arrangement for the passage of the domes through the deck should allow for free movement of the tank and be such that no liquids or gas can enter into the ship.

3.1.3 Tank domes are to be arranged in about the same longitudinal position as the fixed bearer with a view to minimise relative movement between domes and deck structure.

3.1.4 Further requirements for cargo tanks and their placement in the ship are given in Ch 4,3.2 and Ch 4,3.5.

■ *Section 4* Longitudinal strength

4.1 Longitudinal strength requirements

4.1.1 The longitudinal strength is to comply with the requirements of Pt 3, Ch 4 and for this purpose, these ships are, in general, to be considered as Category 'O' ships. The design bending moments of Category 'O' ships may be determined using the formulae in Pt 3, Ch 4,5.

4.1.2 Where in view of service commitments it is desired to load or discharge the ship only according to the loading/ discharge sequence 'T', the longitudinal strength may be based on the requirements for category 'T' ships.

4.1.3 The longitudinal strength may also be based on ‘specified non-uniform loading conditions’ in addition to the loading/discharge sequence ‘T’ or ‘O’ as applicable, in accordance with Pt 3, Ch 4,2.4.1.

4.1.4 The Society reserves the right to require verification by direct calculation for any of the design bending moments calculated in accordance with the above.

■ *Section 5* Hull envelope plating

5.1 General

5.1.1 The hull envelope plating is to comply with the requirements of Ch 5,3.

■ *Section 6* Single bottom structure in way of cargo compartment space

6.1 General

6.1.1 This Section covers the arrangements and requirements for transversely and longitudinally framed single bottoms in way of the cargo compartment space.

6.1.2 The scantlings are based on end connections in accordance with Pt 3, Ch 10,3. Where brackets having arm lengths differing from the standard are fitted, the modulus of the stiffening member is to be corrected in accordance with Pt 3, Ch 10,3.7.

6.1.3 A side girder is to be fitted port and starboard between the centreline and the shell or longitudinal bulkhead near the shell and is to comply with Table 5.6.1.

Table 5.6.1 Single bottom structure in way of cargo compartment space

Item	Parameter	Requirements
Transverse framing system		
(1) Centreline girder, side girders and partial side girders	Web and face plate thickness Width of face plate	$t = 0{,}01d_w + 2{,}5$ mm $b_f = 140s$ mm
(2) Floors	Web depth Web thickness Face plate thickness Face plate width Minimum modulus	$d_w = 40B$ mm $t_w = 0{,}01d_w + 2{,}5$ mm $t = \geq t_w$ mm The greater of: $b_f = 16l_f$ mm $b_f = 100$ mm $Z = 7Tsl_f^{\,2}$ cm^3
(3) Bottom structure supporting cargo tanks (combination of floors with top and bottom plating)	Minimum modulus	$Z = 8{,}5l_f(W - 0{,}3l_f^{\,2}T)$ cm^3
Longitudinal framing system		
(4) Centreline girder, side girders and partial side girders	Web and face plate thickness Width of face plate	$t = 0{,}01d_w + 3$ mm $b_f = 100$ mm
(5) Transverses	Web depth at centreline Web thickness Modulus	$d_w = 40B$ mm $t = 0{,}01d_w + 3$ mm $Z = 7TSl_f^{\,2}$ cm^3
(6) Bottom structure supporting cargo tanks (combination of floors/transverses with top and bottom plating)	Minimum modulus	$Z = 8{,}5l_f(W - 0{,}3l_f^{\,2}T)$ cm^3
(7) Bottom longitudinals	Modulus	$Z = (3{,}95 + 0{,}04L_1)D_1sl_e^{\,2}$ cm^3
Symbols		
L, B, D, T, S, s, l_e, Z and t as defined in 1.10.1 d_w = web depth of girder or floor, in mm l_f = span of floor or transverse, in metres, measured at the top of floor or transverse between side shell or between the longitudinal bulkheads according to 1.2.4(b) D_1 = D but need not be taken greater than T + 0,4 m L_1 = L but is to be taken not less than 40 m, nor more than 100 m W = weight of tanks with maximum weight of cargo supported by the combination of floors or transverses, in tonnes		

6.1.4 Where no centreline bulkhead is fitted, a centreline girder is to be arranged having the same depth as the floors or transverses in way and the scantlings are to comply with Table 5.6.1. Where the spacing between side girders required by 6.1.3 does not exceed 5 m, the centreline girder may be omitted, but efficient support at the centreline is to be arranged for docking purposes.

6.1.5 For ADNR and ADN related structural requirements regarding cargo tank supports, *see* Ch 4,3.5.

6.2 Single bottom structure – Transversely framed ships

6.2.1 Plate floors are to be fitted at every frame and are to comply with the requirements of Table 5.6.1. Floors may be cut at the centreline, with the centre girder web plate continuous, provided the transverse strength of the floors is maintained.

6.2.2 The bottom structure supporting the cargo tanks is to comply with the requirements of Table 5.6.1.

6.2.3 For the purpose of these Rules, the structure is assumed to consist of three to five successive plate floors with a continuous top plate from side to side or between the longitudinal bulkheads according to 1.2.4(b) in association with continuous side girders according to 6.1.3 and at least two partial girders port and starboard, each extending over a length of six to ten frame spaces (*see* Fig. 5.6.1).

6.2.4 The actual arrangement required depends on the total weight of cargo tanks with maximum cargo load. Verification of the structure by direct calculation may be required.

6.2.5 Bottom structures with an arrangement differing from that assumed in 6.2.3, will, in general, be required to be assessed by direct calculations.

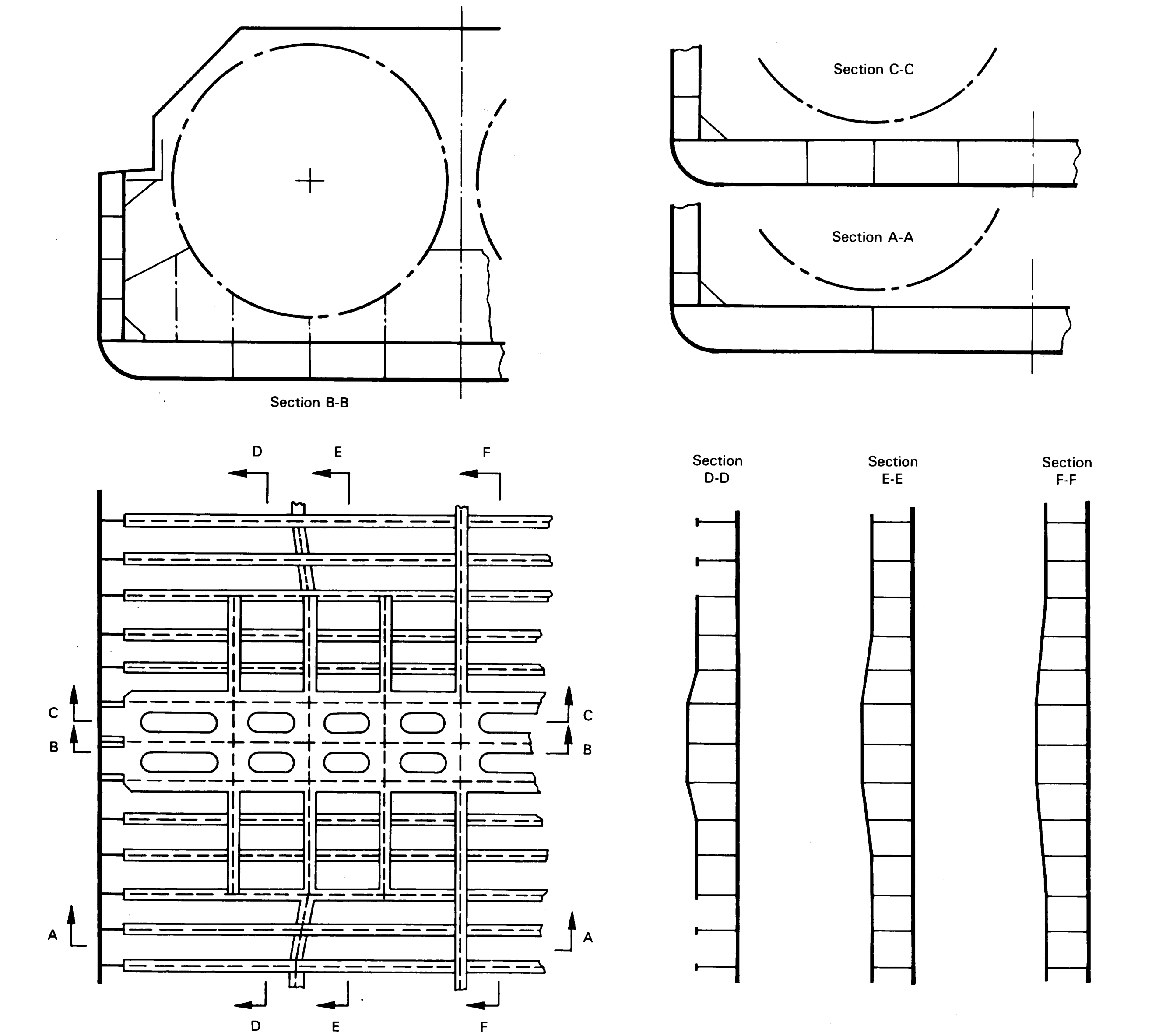


Fig. 5.6.1 Single bottom structure in way of cargo tank support

6.3 Single bottom structure – Longitudinally framed ships

6.3.1 Transverses are to be fitted at a spacing not exceeding 3,5 m and are to comply with the requirements of Table 5.6.1. Vertical stiffeners having a depth of not less than 50 mm are to be fitted to the transverses at every fourth longitudinal.

6.3.2 The bottom structure supporting the cargo tanks is to comply with the requirements of Table 5.6.1.

6.3.3 For the purpose of these Rules, the structure is assumed to consist of three to five floors or transverses, having a spacing of about 0,6 m, with a continuous top plate from side to side or between the longitudinal bulkheads according to 1.2.4(b), in association with continuous side girders according to 6.1.3 and at least two partial girders port and starboard, each extending forward and aft of the support structure over a full bay and in line with bottom longitudinals (*see* Fig. 5.6.1).

6.3.4 The actual arrangement required depends on the total weight of cargo tanks with maximum cargo load. Verification of the structure by direct calculation may be required.

6.3.5 Bottom structures with an arrangement differing from that assumed in 6.3.3, will in general be required to be assessed by direct calculation.

■ *Section 7*
Double bottom structure in way of cargo compartment space

7.1 General

7.1.1 This Section covers the arrangements and requirements for transversely and longitudinally framed double bottoms.

7.1.2 The depth of the double bottom is to be at least as required by Table 5.7.1, and is to be sufficient to ensure the the double bottom spaces are accessible for inspection, surveys, etc., *see also* Ch 6,3.

Table 5.7.1 Double bottom structure in way of cargo compartment space

Item	Parameter	Requirements
Longitudinal and transverse framing system		
(1) Centreline girder, side girders and partial side girders	Minimum depth Thickness	$d_f = 40B$ mm $t = 0{,}01d_f + 2{,}5$ mm
(2) Inner bottom plating	Thickness	The greater of: $t = 12s$ mm $t = 6$ mm
(3) Inner bottom plating in way of tank support structure	Thickness	As bottom shell plating in way
Transverse framing system		
(4) Floors	Thickness	$t = 0{,}007d_f + 3$ mm
(5) Watertight floors	Thickness	$t = 0{,}007d_f + 3{,}5$ mm
(6) Combination of floors in conjunction with bottom and inner bottom plating	Modulus	$Z = 8{,}5l_f\,(W - 0{,}45l_f^2 T)$ cm^3
(7) Floors and watertight floors	Thickness	$t = 0{,}0085d_f + 3{,}5$ mm
(8) Combination of floors in conjunction with bottom and inner bottom plating	Modulus	$Z = 8{,}5l_f\,(W - 0{,}45l_f^2 T)$ cm^3
(9) Bottom longitudinals	Modulus	$Z = (3{,}95 + 0{,}04L_1)\,D_1 s l_e^2$ cm^3
(10) Inner bottom longitudinals	Modulus	$Z = 6{,}75\left(T - \frac{d_f}{1000}\right) s l_e^2$ cm^3
Symbols		
L, B, D, T, s, l_e, Z and t are as defined in 1.10.1 D = depth of girders or floors, in mm L = span of floor, in metres, measured at the top of floor between side shell or between longitudinal bulkheads according to 1.2.4(b) D_1 = D but need not be taken greater than T + 0,4 m L_1 = L but is to be taken not less than 40 m, nor more than 100 m W = weight of tanks with maximum weight of cargo supported by the combination of floors, in tonnes		

7.1.3 Provision is to be made for free passage of air to the ventilation pipes and where the double bottom spaces are to be used as ballast tanks, also for free passage of water to the tank suctions, account being taken of the pumping rates required. Where access openings are cut in the floors, girders or transverses, the height of the openings is not, in general, to exceed 50 per cent of the double bottom depth. Openings are to be avoided in ends of floors.

7.1.4 The depth of the double bottom in way of the support for the cargo tanks may require to be increased in height to meet the strength requirements in way.

7.1.5 For ADNR and ADN related structural requirements regarding cargo tank supports, *see* Ch 4,3.5.

7.2 Girders

7.2.1 A centreline girder is generally required in ships with a breadth, *B*, of more than 6 m. A side girder is to be fitted on each side of the centreline in ships having a breadth, *B*, or more than 12 m and transversely framed bottom construction. Proposals to omit the centreline girder and/or side girders will be specially considered, but adequate support must be provided on the centreline for docking purposes.

7.3 Transversely framed double bottoms

7.3.1 Plate floors are generally to be fitted at every frame and are to comply with Table 5.7.1. Plate floors may be cut at the centreline with the centerline girder web plate continuous, provided the transverse strength of the floors is maintained.

7.3.2 As an alternative to 7.3.1, bracket floors may be fitted in association with plate floors spaced not more than 2,5 m apart. Scantlings and arrangements of bracket floors are to comply with the requirements for such floors in double bottoms in the forward end and aft end as indicated in Pt 3, Ch 5,3.

7.3.3 The bottom structure supporting the cargo tanks is to comply with the requirements of Table 5.7.1. The structure is to consist of three to five successive plate floors in conjunction with inner bottom plating of increased thickness from side to side or between the longitudinal bulkheads according to 1.2.4(b) in association with continuous side girders according to 7.2.1 and at least two partial girders port and starboard, each extending over a length of six to ten frame spaces, *see* Fig. 5.7.1. Where no continuous side girders are provided, at least three partial girders are to be fitted on each side.

7.3.4 The actual arrangement required depends on the total weight of cargo tanks with maximum cargo load. Verification of the structure by direct calculation may be required.

7.3.5 Bottom structures with an arrangement differing from that assumed in 7.3.3, will, in general, be required to be assessed by direct calculation.

7.4 Longitudinally framed double bottoms

7.4.1 Plate floors are to be fitted at a spacing not exceeding 3,5 m.

7.4.2 The bottom structure supporting the cargo tanks is to comply with the requirements of Table 5.7.1. The structure is, in general, to be identical to that required by 7.3.3. The plate floors are to have about the same spacing as the longitudinal framing and the partial girders are to extend forward and aft of the support structure over a full bay.

7.4.3 The actual arrangement required depends on the total weight of cargo tanks with maximum cargo load. Verification of the structure by direct calculation may be required.

7.4.4 Bottom structures with an arrangement differing from that assumed in 7.4.2, will in general be required to be assessed by direct calculation.

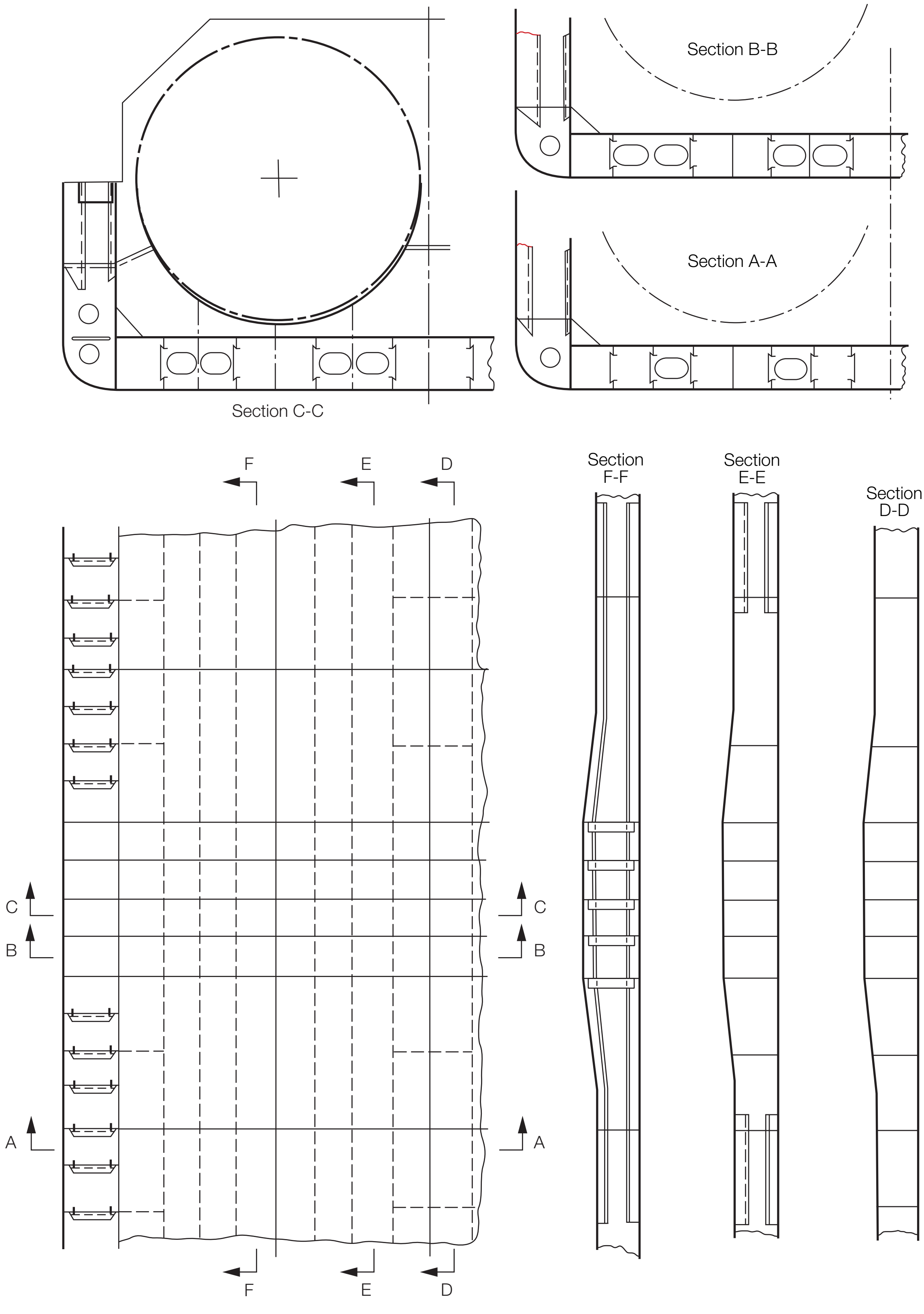


Fig. 5.7.1 Double bottom structure in way of cargo tank support

Section 8
Side shell framing in way of cargo compartment space

8.1 General

8.1.1 This Section covers the arrangements and requirements for side shell transverse and longitudinal framing.

8.1.2 The scantlings required are based on end connections in accordance with Pt 3, Ch 10,3. Where brackets having arm lengths differing from the standard are fitted, the modulus of the stiffening member is to be corrected in accordance with Pt 3, Ch 10,3.7.

8.1.3 The width of a double skin, where fitted, is not to be less than 0,80 m.

8.1.4 Care is to be taken to maintain adequate transverse strength in way of the side compartments.

8.2 Transverse framing

8.2.1 The scantlings of the side framing are to comply with Table 5.8.1.

8.2.2 Web frames are to be fitted at every floor of the bottom structure supporting the cargo tanks.

8.3 Longitudinal framing

8.3.1 The scantlings of the longitudinal framing are to comply with Table 5.8.1.

8.3.2 Side transverses are to be arranged in line with bottom and deck transverses to form a ring system for support of the side longitudinals.

8.3.3 Web frames are to be fitted at every floor of the bottom structure supporting the cargo tanks.

8.4 Reinforcement of single skin side shell

8.4.1 For ADNR and ADN related structural requirements regarding minimum structural requirements for single skin sideshell structures, *see* Ch 4,3.5.

8.4.2 The depth of the web frames and stringers is to be at least twice the depth of the slot cut for longitudinal or transverse frames.

Table 5.8.1 Side shell framing

Item	Parameter	Requirements
Transverse framing		
Side frames	Modulus	$Z = 7s\, l_e^2\, h_f$ cm^3
Side frames of combination		$Z = 7s\, l_e^2\, h_f$ cm^3
System (bottom and deck longitudinally framed and sides transversely framed)	Modulus	*See* Note
Longitudinal framing		
Side shell longitudinals	Modulus	$Z = (4,6 + 0,0342L_1)\, s\, l_e^2\, h_f$ cm^3
Side transverses	Modulus	$Z = 10S\, l_e^2\, h_f$ cm^3
Transversely and longitudinally framed ships		
Web frames in way of floors/transverses of bottom structure supporting the cargo tanks	Web depth Modulus	The greater of: 0,1D mm; 300 mm $Z = 40S\, l_e^2$ cm^3
Symbols		
L, D, T, S, s, l_e, and Z are as defined in 1.10.1 h_f = $h_{de} + h_t$ but not less than 2,0 m h_{de} = the vertical distance of the stiffening member under consideration to the deck at side h_t = 0 for void spaces, or 0,50 m for deeptanks but not less than the actual distance of the top of the overflow above deck L_1 = L but is to be taken not less than 40 m, nor more than 100 m W = weight of tanks with maximum weight of cargo supported by the combination of floors, in tonnes		
NOTE The section modulus of side frames in way of bottom and deck transverses is to be increased by 100 per cent.		

Section 9
Longitudinal bulkheads

9.1 General

9.1.1 This Section covers the requirements for compliance with 1.2.4(b).

9.2 Structural requirements

9.2.1 The construction of the longitudinal bulkheads is to comply with the requirements for vertically stiffened watertight bulkheads according to Pt 3, Ch 7,2. Where the space between the longitudinal bulkheads and the side shell is designated to be used for water ballast purposes, the scantlings are to be in accordance with the requirements for deep tanks.

9.2.2 Struts are not to be used to connect longitudinal bulkhead stiffeners to the side shell structure in order to avoid possible damage to bulkheads in case of collisions.

9.2.3 Watertight transverse bulkheads are to be fitted between the shell and the longitudinal bulkheads in such a way that the ADNR damage stabilty requirements are fulfilled. *See also* Ch 4,1.7.

Section 10
Deck support structure

10.1 General

10.1.1 The deck support structure is to comply with Table 5.10.1.

Table 5.10.1 Deck support structure

Item	Parameter	Requirements
Transverse framing		
Deck beams in flush deck ships Trunk deck beams	Modulus	$Z_b = 3{,}1 s\, l_e^2$ cm^3
Trunk side stiffeners Deck beams abreast trunks	Modulus	$Z = Z_b$ cm^3
Deck girders	Modulus	$Z = (0{,}33 + 0{,}062 L_1)\, S\, l_e^2$ cm^3
Longitudinal framing		
Deck longitudinals in flush deck ships Trunk deck longitudinals	Modulus	$Z = (0{,}073 L_1 - 0{,}5)\, s\, l_e^2$ cm^3
Trunk side longitudinals Deck longitudinals abreast trunks	Inertia	$I = 2{,}3 l_e^2\, Z$ cm^4
Deck transverses in flush deck ships Trunk deck transverses	Modulus	$Z_t = 3{,}1 S\, l_e^2$ cm^3
Trunk side transverses Deck transverses abreast trunks	Modulus	$Z = Z_t$ cm^3
Symbols		
L, S, s, l_e, Z and I are as defined in 1.10.1 L_1 = L but is to be taken as not less than 50 m, nor more than 100 m		

Section 11
Direct calculation procedures

11.1 General

11.1.1 This Section contains guidance for direct calculations, information regarding maximum permissible stresses and minimum requirements for structural members included in the hull midship section modulus and for other structural members which do not form part of the hull midship modulus.

11.1.2 Direct calculations are to be carried out as required by the Rules and may be used as an alternative to derrive scantlings instead of Rule formulae, or for the assessment of scantlings of structural members not covered by the Rules.

11.1.3 Where direct calculation is carried out, calculation results are to be submitted together with all data in support of the calculation e.g. support conditions and details of loads.

11.2 Permissible stresses

11.2.1 In addition to the permissible stresses given in Pt 3, Ch 4,6 the following stress criteria are to be applied:

(a) For structural members included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in Table 5.11.1.

(b) For structural members not included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in Table 5.11.2.

Table 5.11.1 Maximum permissible stresses in longitudinal continuous members, in N/mm^2 (kgf/mm^2)

Item	Local bending stress, σ_b *See* Note 1	Combined bending stress, σ_b	Shear stress, τ	Equivalent stress, σ_e *See* Note 2
Bottom girders Deck girders	108 (11,0)	177 (18,0)	83 (8,5)	188 (19,2)
Bottom longitudinals Inner bottom longitudinals Deck and trunk deck longitudinals Side shell longitudinals	137 (14,0)	177 (18,0)	83 (8,5)	188 (19,2)

NOTES
1. The combined stress, σ_c, is the sum of the stresses due to longitudinal bending and local loading.
2. The equivalent stress, σ_e, is to be calculated according to the formula

$$\sigma_e = \sqrt{\sigma_c^2 + 3\tau^2}$$

Table 5.11.2 Maximum permissible stresses in local members, in N/mm^2 (kgf/mm^2)

Item	Local bending stress, σ_b	Shear stress, τ	Equivalent stress, σ_e *See* Note 1
Non-continuous bottom girders, side stringers (*see* Note 2), deck beams, deck transverses and non-continuous deck girders	124 (12,6)	83 (8.5)	177 (18,0)
Floors, bottom transverses and bottom structure supporting tanks	116 (11,8)	83 (8,5)	172 (17,5)
Side frames	113 (11,5)	83 (8,5)	172 (17,5)
Webs supporting side stringers and side transverses (*see* Note 2)	103 (10,5)	83 (8,5)	167 (17,0)

NOTES
1. The equivalent stress, σ_e, is to be calculated according to the formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$$

2. The scantlings of stringers, or web frames fitted to comply with the requirements of 1.2.4(a) are not to be determined by direct calculation but are to be in accordance with 8.4.

11.3 Structural requirements

11.3.1 As a first approximation the structural components may be determined according to the requirements of the preceding Sections of this Chapter.

11.3.2 In addition to the maximum permissible stresses given in 11.2, the following minimum plating thickness requirements are to be complied with:

(a) The thickness of bottom plating and side shell plating amidships is to be not less than the thickness of shell plating at ends, *see* Pt 3, Ch 5,2.

(b) The thickness of the bilge plating amidships is to be 2 mm greater than the bottom plating, in way.

(c) The minimum thickness of the deck plating is to be not less than the thickness of deck plating at ends, *see* Pt 3, Ch 5,2.

(d) Depending on the level of compressive stresses, additional buckling calculations may be required.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to propelled and non-propelled tankers (barges) of Types C, N Closed, N Open with flame arrestors and N Open, intended for the carriage of dangerous liquid oil and chemical cargoes of Classes 3, 6.1, 8 and 9 in bulk, in association with a List of Defined Chemical Cargoes and with class notations as indicated in 1.4.

1.1.2 For further information on international regulations, the significance of tanker types and further information on dangerous liquids, *see* Chapter 4.

1.1.3 This Chapter mainly provides for requirements regarding structural aspects. For basic midship configurations and particular aspects and requirements regarding the design and arrangements of Type C and Type N tankers, *see* Chapter 4.

1.1.4 Alternative arrangements which are proposed as being equivalent to the Rules will receive individual consideration taking into account any relevant National Authority requirements.

1.1.5 The requirements of this Chapter take into account the ADNR Regulations of the Central Rhine Commission and the European Provisions concerning the International Carriage of Dangerous Goods by Inland Waterway (ADN) which assume heavy traffic on relatively narrow waterways through heavily populated areas.

1.1.6 Ships intended to be used on waterways with conditions different from those stated in 1.1.4 and where ADNR and ADN requirements are not applicable will receive special consideration and the requirements may be modified to suit the actual conditions, *see also* Ch 4,1.2.

1.1.7 Although the contents of this Chapter and those of Chapter 4 take ADNR and ADN technical Regulations into account, the issue of an ADNR certificate by or on behalf of the relevant Authorities, requires full compliance with their Regulations which are to be consulted in all cases.

1.1.8 Where requested to do so by the Builder or Owner, Lloyd's Register (hereinafter referred to as LR) will investigate compliance with the ADN Recommendations or ADNR Regulations indicated in 1.1.7 with a view to issuing a Statement of Compliance.

1.2 Ship arrangement

1.2.1 Self-propelled tankers are to have the machinery aft.

1.2.2 For ADNR and ADN related requirements such as the arrangement of cofferdams, double sides (as applicable), service spaces and accommodations, entrances and the protection against the ingress of gases and special requirements for Type C and N tankers, *see* Ch 4,3.

1.2.3 The maximum tank capacity in accordance with the ADN(R) is to be determined in accordance with Ch 4,3.2. The ADN(R), however, offers deviations of the prescribed tank capacities, provided the crashworthiness of the vessel is suitably increased. This may be achieved by one, or a combination of the following measures described in 1.3.4.

1.2.4 Arrangements and scantlings forward and aft of the midship region are to comply with Pt 3, Ch 5 and Pt 3, Ch 6 so far as applicable. The remaining requirements of Part 3 are also to be complied with as appropriate for the intended arrangements.

1.3 Structural configuration

1.3.1 The arrangement and requirements in the following Sections are for tankers having a length not exceeding 135 m, a ratio of length to depth not exceeding 35, a ratio of breadth to depth not exceeding 5 and the midship region as defined in Pt 3, Ch 3,2.1. When the limiting length of the ship or ratio of *L*/D or *B/D* are exceeded, the scantlings may have to be determined by direct calculation, *see* Pt 3, Ch 1,3.2 and Pt 3, Ch 4.

1.3.2 This Chapter provides for a basic structural configuration of ships having integral cargo tanks of the flush deck (Type C or Type N) or the trunk deck (Type N) type. It also provides for the structural configuration of ships having tanks independent from the ship's structure, *see* Sections 8 and 9.

1.3.3 The bottom, side shell and deck plating may be framed transversely or longitudinally or a combination of the two, but it is recommended that ships over 50 m in length be built according to the longitudinal framing system in bottom and deck.

1.3.4 In case the ship is provided with tanks exceeding the maximum tank capacity in accordance with the ADN(R) as described in 1.2.3, one, or a combination of the following measures, need to be taken:

- Increase in sideshell and/or tank plating thicknesses, increase of stiffening arrangements or scantlings and spacings of primary members.
- Increase in the overall width of the double skin.
- Introduction of additional structural members.
- The appliance of special crashworthy structures.
- The use of alternative materials. The use of these materials is to be approved by the Society.

In the above cases, the increased collision capabilities are to be proven by additional direct and statistical calculations as required by the ADN(R). These calculations should be submitted to, and be approved by the Society.

1.4 Class notation

1.4.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2,2.

1.4.2 Type C Tankers complying with the requirements of this Chapter and other relevant Rule requirements will be eligible to be classed:

'A1 I.W.W. Tanker Type C'

or

'A1 I.W.W. Barge Type C'

together with the appropriate design pressure valve setting and design specific gravity and in association with a List of Defined Cargoes, e.g.:

'A1 I.W.W. Tanker Type C, p.v. +50 kPa, S.G. 1.20 in association with a List of Defined Cargoes'.

1.4.3 Type N Closed Tankers complying with the requirements of this Chapter and other relevant Rule requirements will be eligible to be classed:

'A1 I.W.W. Tanker Type N Closed'

or

'A1 I.W.W. Barge Type N Closed'

together with the appropriate design pressure valve setting and design specific gravity and in association with a List of Defined Cargoes, e.g.:

'A1 I.W.W. Tanker Type N Closed, p.v. +25 kPa, S.G. 1.00 in association with a List of Defined Cargoes'.

1.4.4 Type N Open Tankers with flame screens complying with the requirements of this Chapter and other relevant Rule requirements will be eligible to be classed:

'A1 I.W.W. Tanker Type N Open with flame screens'

or

'A1 I.W.W. Barge Type N Open with flame screens'

together with the appropriate design specific gravity and in association with a List of Defined Cargoes, e.g.:

'A1 I.W.W. Barge Type N Open with flame screens, S.G. 1.00 in association with a List of Defined Cargoes'.

1.4.5 Type N Open Tankers complying with the requirements of this Chapter and other relevant Rule requirements will be eligible to be classed:

'A1 I.W.W. Tanker Type N Open'

or

'A1 I.W.W. Barge Type N Open'

together with the appropriate design specific gravity and in association with a List of Defined Cargoes, e.g.:

'A1 I.W.W. Tanker Type N Open, S.G. 1.50 in association with a List of Defined Cargoes'.

1.4.6 Type N Tankers complying with the requirements of Ch 4,3.7.1 and other relevant ADN(R) requirements will be eligible to receive the additional notation 'Double Hull', e.g.: 'A1 I.W.W. Tanker Type N Closed, Double Hull, p.v. +25 kPa, S.G. 1.00 in association with a List of Defined Cargoes'.

1.4.7 Other notations, as appropriate to the arrangements, scantlings and service, may be assigned as provided for in Pt 1, Ch 2,2.

1.5 List of Defined Cargoes

1.5.1 The List of Defined Chemical Cargoes, for the carriage of which the ship has been approved, will be attached to the Classification Certificate.

1.5.2 Only those chemical cargoes which are included in the List of Defined Chemical Cargoes may be carried.

1.5.3 The List of Defined Cargoes will be issued by the Society and will be based on Table C of Part 3 of the A.D.N.R. Parameters will include the tanker type, cargo tank design and cargo tank type as well as the characteristics of all relevant equipment fitted in the cargo zone. All relevant requirements of Table C will be used as a basis for the list, including any relevant additional requirements contained in column 20. Attention is drawn to Ch 4,1.5.3 and Ch 4,1.5.4 in respect of material compatibility.

1.6 Additional notations

1.6.1 Additional notations may be assigned for the following features:

- Tanks constructed of corrosion resistant materials, e.g. stainless steel 'CR (s.stl)', or lined with corrosion resistant linings, e.g. rubber lining 'CR (r.l)'.

1.7 Heated cargoes

1.7.1 Where it is intended to carry cargoes at temperatures higher than 80°C in integrated tanks, a thermal stress calculation needs to be submitted for verification of the scantlings and arrangements.

1.8 Materials

1.8.1 For materials and grades of steel, the use of materials and protection of steelwork, reference is made to Ch 4,2.

1.9 Stainless steel

1.9.1 The material is to comply with the requirements of Ch 4,2 and Ch 3,7 of LR's *Rules for the Manufacure, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Other types of stainless steel will be specially considered.

1.9.2 The use of clad stainless steel instead of solid stainless steel will be specially considered.

1.9.3 Where the specified minimum yield stress or 0,5 per cent proof stress at the operating steel temperature is less than 235 N/mm^2 (24 kgf/mm^2), scantlings will have to be increased and will be specially considered.

1.10 Compartment minimum thickness

1.10.1 Within the cargo tank region, including cofferdams and under deck pump-rooms, the thickness of all plating and structural members is to be not less than:

t = 0,025(135 + L) mm

L is the Rule length of the ship, in metres, which is to be taken as not less than 65 m.

1.10.2 For stainless steel structures, the thickness obtained with 1.10.1 may be reduced by 0,5 mm.

1.11 Information required

1.11.1 For the information required to be submitted, *see* Pt 3, Ch 1,5. In addition, the following are to be supplied:

(a) The desired tanker type notation and the cargo tank type.
(b) The opening pressure of the high velocity vent valves.
(c) The proposed design cargo relative density (specific gravity).
(d) Maximum cargo temperature in °C when loaded or carried.
(e) Details of corrosion protection of cargo tanks, ballast spaces and void spaces if applied.
(f) Details of materials to be used in the construction of the cargo tanks if not made of mild steel.
(g) Loading sequence desired and data on any other non-uniform loading conditions that may be applicable.
(h) The flag of the vessel and the country issuing statutory certificates.
(j) Any other relevant information that may influence the design of the ship or the proceedings during the approval process.

1.12 Symbols and definitions

1.12.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D, T are as defined in Pt 3, Ch 1,6.1

h_d = cargo tank design pressure head
= for Type N Open tankers and for Type N Open tankers with flame screens: 0,6 m
= for Type N Closed and Type C tankers: The design pressure head as required by the specifications for the ship but not less than 1,02 m (10 kPa design pressure) and not greater than 5.10 m (50 kPa design pressure)

l_e = effective length of stiffening member, in metres, *see* Pt 3, Ch 3,3.3

s = spacing of secondary stiffeners, i.e. frames, beams, or stiffeners, in metres

t = thickness of plating, in mm

I = inertia of stiffening member, in cm^4, *see* Pt 3, Ch 3,3.2

S = spacing, or mean spacing, of primary members, i.e. girders, transverses, webs, etc., in metres

Z = section modulus of stiffening member, in cm^3, *see* Pt 3, Ch 3,3.2

ρ = relative density (specific gravity), but is to be taken as not less than 1 tonne/m^3.

■ *Section 2* Longitudinal strength

2.1 Longitudinal strength requirements

2.1.1 The longitudinal strength is to comply with the requirements of Pt 3, Ch 4. and for this purpose, these ships are, in general, to be considered as Category 'T' ships. For this purpose, the design bending moments of Category 'T' ships may be determined using the formulae in Pt 3, Ch 4,5.

2.1.2 If the ship is to be loaded or discharged, according to the loading/discharge sequence 'O' or equivalent in view of service commitments, the longitudinal strength is to be based on the requirements for Category 'O' ships.

2.1.3 The longitudinal strength may be based on a defined loading/discharge sequence 'D' in accordance with Pt 3, Ch 4,2.3.1.

2.1.4 The longitudinal strength may also be based on 'Specified non-uniform loading conditions' in addition to the loading/discharge sequence 'T' or 'O' as applicable, in accordance with Pt 3, Ch 4,2.4.1.

2.1.5 The Society reserves the right to require verification by direct calculation for any of the design bending moments calculated in accordance with the above.

■ *Section 3* Hull envelope plating

3.1 General

3.1.1 This Section covers the arrangements and requirements for the hull envelope plating for flush and trunk deck tankers *viz*: keel, bottom, bilge, side shell plating, sheerstrake, deck, trunk side and trunk deck plating so far as applicable. Tankers of Type C are to be of the flush deck type, *see also* Ch 4,3.6.

3.1.2 The thickness of the hull envelope plating amidships is to be not less than required in this Section, but in ships over 40 m in length, the thickness of bottom plating and top side plating (and/or longitudinal stiffening members) may require to be increased to obtain the midship section modulus as required in Pt 3, Ch 4.

3.1.3 The midship thicknesses are to be maintained over 0,5*L* amidships, except where stated otherwise in this Section and may be tapered to the end thicknesses in the fore and aft ends of the ship, *see* Pt 3, Ch 5, according to the requirements for taper given in Pt 3, Ch 3,2.5.

3.1.4 Openings in the shell plating are to have well rounded corners; compensation is, generally, only required for openings having a width greater than 250 mm. Openings in way of, or near to the bilge radius are to be circular or elliptical.

3.1.5 Where openings are made in the deck plating for access to tanks, the deck plating in way is, generally, to be increased in thickness to compensate for the material cut out. Where a deck longitudinal is cut in way of an opening, compensation is to be arranged to ensure full continuity of sectional area. However, no compensation need be fitted if the loss of sectional area has already been taken into consideration in calculating the actual midship hull section modulus.

3.1.6 Circular openings in the deck of a diameter of 150 mm or less need not be compensated, provided they are situated well clear of other openings and the area cut out transversely over the deck does not exceed three per cent of the total area.

3.1.7 Plate panels, in which openings are cut are, where necessary, to be adequately stiffened against compression.

3.2 Keel

3.2.1 The breadth and thickness of the keel is to comply with the requirements of Table 6.3.1 and is to be maintained over the full length of the ship.

3.3 Shell plating

3.3.1 The thickness of the bottom plating and side shell plating is to comply with the requirements of Table 6.3.1.

3.3.2 When local doublers are used on the sideshell plating to act as rubbing bars, full penetration welding of the buttwelds is to be ensured and suitable backing bars or copper shims are to be used for welding the buttwelds to prevent actual attachment to the shell plating in way. The doublers are to be attached to the sideshell plating with seam welding only after individual welding of the buttwelds as described above. Doublers are not to be used in lieu of the inserted sheerstrake required by 3.5. Doublers are not to be included in the calculation of the hull section modulus.

3.3.3 Where a reduced width of the double skin is proposed on Type C tankers, the thickness of the sideshell plating is to be increased, *see* 3.11.2.

3.4 Bilge plating

3.4.1 The thickness of the bilge plating amidships is to comply with the requirements of Table 6.3.1, and is to be maintained from well beyond the forward shoulder to well beyond the aft shoulder of the bilge, but at least over the midship region. For definition of shoulders, *see* Pt 3, Ch 5,2.4.

3.4.2 The bilge radius is to be at least 10 times the thickness of the bilge plating and is to extend at least 100 mm on either side of the radius of the bilge plate.

3.4.3 Square bilges, constructed by solid round, square, or externally fitted angle bars, *see* Fig. 6.3.1, are to comply with Table 6.3.1. The bottom plating and the side shell plating, adjacent to the round, square or angle bars, need not be increased in thickness above that of the bottom plating or side shell plating in way.

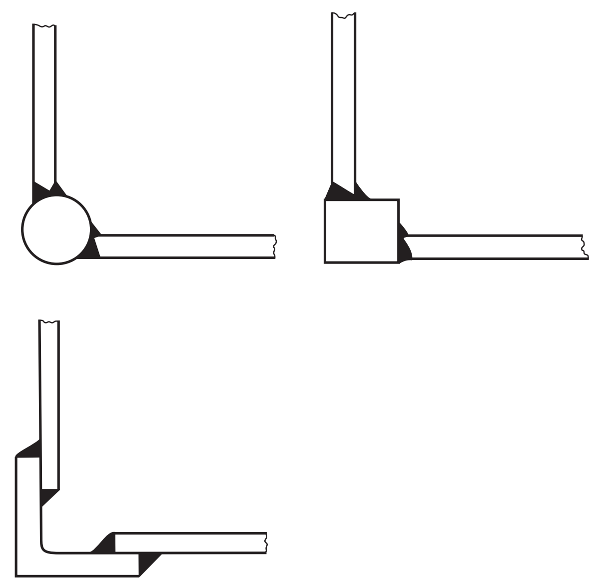


Fig. 6.3.1 Square bilge arrangements

Table 6.3.1 Hull envelope plating and inner bottom plating – All tankers (*see continuation*)

Item and parameter	Required minimum scantlings (*See* Note 1)	
(1) Plate keel Breadth Thickness	0,1B m, but not less than 0,75 m As bottom plating, t_b When there is a rise of floor, the thickness is to be increased by 1 mm	
	Longitudinal framing	Transverse framing
(2) Bottom plating Thickness *See* Note 2	The greater of: $t_b = (5,6 + 0,054L)\sqrt{s}$ mm $t_b = 10s$ mm	$t_b = (5,6 + 0,054L)\sqrt{s}$ mm $t_b = 10s$ mm
	But for ships with a length, L, exceeding 40 m, t_b is to be not less than:	
	The greater of: $t_b = 0,076 \dfrac{M}{B \times D_1} - \dfrac{a_1}{10B}$ mm $t_b = 2,3 \sqrt[3]{\dfrac{MH \times s^2}{B \times D_1}}$ mm	The greater of: $t_b = 0,076 \dfrac{M}{B \times D_1} - \dfrac{a_1}{10B}$ mm $t_b = 2,85 \sqrt[3]{\dfrac{MH \times s^2}{B \times D_1 \times C_1}}$ mm
(3) Bilge plating Thickness	Longitudinal and transverse framing $t_b = t_b + 2$ mm	
(4) Bilge chine bars (a) (b (c)	Round bars Diameter Square bars Width Angle bars Flange thickness	 3t_b mm, but not less than 30 mm 3t_b mm, but not less than 30 mm $t_b = 2t_b$ mm
(5) Side shell plating Thickness *See* Note 2	The greater of: $t_b = (5,6 + 0,054L)\sqrt{s}$ mm $t_b = 10s$ mm	
(6) Sheerstrake Width Thickness	0,08D mm but not less than 0,2 m $t = t_s + 5$ mm, *see* Note 3	
(7) Doublers clear of sheerstrake (when fitted) Width Thickness	$W_d =$ between 0,10 and 0,45 m The greater of: $t = 30W_d$ $t = t_s$	
(8) Inner bottom plating	The greater of: $t = 12s$ mm $t = 4s\sqrt{h_g} + K_c$ mm	
Symbols		

L, B, D, T, S, s and t as defined in 1.12.1

a_1 = total area of bottom longitudinals, in cm^2
h_g = as defined in Table 6.4.1
K_c = plate thickness factor = 1,5 for mild steel
For stainless steel, *see* Table 6.7.2
t_b = thickness of bottom plating, in mm
t_s = required minimum thickness for the sideshell plating calculated at the same location, in mm
$C_1 = 1 + 3\left(\dfrac{s}{S}\right)^2$, where $\dfrac{s}{S}$ is the ratio of the unstiffened bottom panel under consideration
D_1 = depth D for flush deck tankers and depth to trunk deck for trunk deck tankers
M = the greater of MS and MH
MH = maximum design hogging bending moment, in tm, *see* Pt 3, Ch 4
MS = maximum design sagging bending moment, in tm, *see* Pt 3, Ch 4

Table 6.3.1 Hull envelope plating and inner bottom plating – All tankers (*conclusion*)

NOTES
1. The minimum compartment thickness of the tank structure is not to be less than as required by 1.10.
2. For single skin tankers intended for the carriage of cargoes having relative densities (specific gravities) in excess of 1,0 and for single skin tankers with design vapour pressures in excess of 10 kPa, the thickness is also to comply with the requirements for tank boundary plating, in accordance with Section 7, whereby a minimum draught of 0,4T may be assumed to represent the counter-effect of outside water pressure.
3. For ships up to a length, L, of 65 m, where a substantial welded steel rubbing bar is fitted, the sheerstrake may be of the same thickness as the side shell in way.

3.5 Sheerstrake

3.5.1 The width and the thickness of the sheerstrake is to comply with the requirements of Table 6.3.1.

3.5.2 In case of a rounded gunwale or when the sheerstrake is of the 'tumble home' type, a strake of increased thickness is to be fitted as high as possible, covering the area where the ship has its maximum width. The thickness and extent are to comply with 3.5.1.

3.5.3 In case of a rounded gunwale the radius of the curvature of the strake is not to be less than 10 times the actual plating thickness.

3.5.4 Where a reduced width of the double skin is proposed on Type C tankers, the thickness of the sheerstrake plating is to be increased, *see* 3.11.2.

3.6 Deck plating of transversely framed flush deck tankers

3.6.1 The thickness of the deck plating is to comply with the requirements of Table 6.3.2.

3.6.2 Where a reduced width of the double skin is proposed on Type C tankers, the thickness of the deck plating is to be increased, *see* 3.11.2.

3.7 Trunk deck plating, trunk side plating and plating of deck abreast trunk of transversely framed trunk deck tankers

3.7.1 The thickness of plating of the trunk deck, trunk side and deck abreast of the trunk is to comply with the requirements of Table 6.3.3.

3.8 Deck plating of longitudinally framed flush deck tankers

3.8.1 The thickness of the deck plating is to comply with the requirements of Table 6.3.2.

3.8.2 Where a reduced width of the double skin is proposed on Type C tankers, the thickness of the deck plating is to be increased, *see* 3.11.2.

Table 6.3.2 Hull envelope plating – Flush deck tankers deck plating

Item and parameter	Longitudinal framing	Transverse framing
Deck plating: Thickness *See* Note	The greater of: $t = (5{,}6 + 0{,}039L)\sqrt{s}$ mm $t = 10s$ mm	The greater of: $t = (5{,}6 + 0{,}039L)\sqrt{s}$ mm $t = 10s$ mm
	but for ships with a length, L, exceeding 40 m, t is to be not less than:	
	The greater of: $t = 0{,}076\dfrac{M}{B \times D} - \dfrac{a_1}{10B}$ mm $t = 2{,}3\sqrt[3]{\dfrac{MH \times s^2}{B \times D}}$ mm	The greater of: $t = 0{,}076\dfrac{M}{B \times D}$ mm $t = 2{,}85\sqrt[3]{\dfrac{MS \times s^2}{B \times D \times C_1}}$ mm
Symbols		
L, B, D, S, s and t as defined in 1.12.1 a_1 = total area of deck longitudinals, in cm^2 $C_1 = 1 + 3\left(\dfrac{s}{S}\right)^2$, where $\dfrac{s}{S}$ is the ratio of the unstiffened bottom panel under consideration M = the greater of MS and MH MH = maximum design hogging bending moment, in tm, *see* Pt 3, Ch 4 MS = maximum design sagging bending moment, in tm, *see* Pt 3, Ch 4		
NOTE The minimum compartment thickness of the tank structure is not to be less than as required by 1.10.		

3.9 Trunk deck plating, trunk side plating and plating of deck abreast trunk of longitudinally framed trunk deck tankers

3.9.1 The thickness of plating of the trunk deck, trunk side and the deck abreast of the trunk is to comply with the requirements of Table 6.3.3.

3.10 Inner bottom plating

3.10.1 The thickness of the inner bottom plating is to comply with the requirements of Table 6.3.1.

3.11 Double skin arrangement

3.11.1 Where a double skin is fitted and the inner skin forms the boundary of cargo tanks, the plating of the inner skin is to comply with the requirements of Section 7 for tank bulkhead plating. Otherwise the plating of the inner skin is to comply with the requirements for deep tank or watertight bulkheads, as applicable, *see* Pt 3, Ch 7.

3.11.2 For details regarding the accessibility and the standard required width of the double skin on Type C tankers, reference is made to Ch 4,3.6. Requirements are also given for strengthening the double skin in cases where the width is reduced to the minimum value as allowed by the ADN(R). In this case, the required percentages of increase in thicknesses of the deck, sideshell and sheerstrake plating as given in Ch 4,3.6 are to be applied to the minimum values as calculated by using this Chapter.

Table 6.3.3 Hull envelope plating – Trunk deck tankers trunk plating and deck plating

Item and parameter	Longitudinal framing	Transverse framing
(1) Trunk deck plating Thickness *See* Note	The greater of: $t_{trd} = (5,6 + 0,039L)\sqrt{s_t}$ mm $t_{trd} = 10s_t$ mm	The greater of: $t_{trd} = (5,6 + 0,039L)\sqrt{s}$ mm $t_{trd} = 10s_t$ mm
	but for ships with a length, L, exceeding 40 m, t_{trd} is to be not less than:	
	The greater of: $t_{trd} = 0,076 \dfrac{M}{B_{trd} \times D_{trd}} - \dfrac{a_{1trd}}{10B_{trd}}$ mm $t_{trd} = 2,3 \sqrt[3]{\dfrac{MH \times s_t^2}{B_{trd} \times D_{trd}}}$ mm	The greater of: $t_{trd} = 0,076 \dfrac{M}{B_{trd} \times D_{trd}}$ mm $t_{trd} = 2,3 \sqrt[3]{\dfrac{MS \times s^2}{B_{trd} \times D_{trd} \times D_{trd}}}$ mm
(2) Trunk side plating Thickness, *see* Note	The greater of: $t = t_{trd}$ mm $t = t_{trd}\sqrt{\dfrac{s_{ts}}{s_t}}$ mm	The greater of: $t = t_{trd}$ mm
(3) Deck plating abreast trunk Thickness, *see* Note	The greater of: $t = 0,9t_{trd}\sqrt{\dfrac{s_d}{s_t}}$ mm $t = (5,6 + 0,039L)\sqrt{s_t}$ mm $t = 10s_d$ mm	The greater of: $t = 0,9t_{trd}$ mm $t = (5,6 + 0,039L)\sqrt{s_t}$ mm $t = 10s$ mm

Symbols

L, s and t as defined in 1.12.1

a_{1trd} = total area of trunk deck longitudinals, in cm^2
s = spacing of transverse deck beams, in metres
s_d = spacing of longitudinals of deck abreast trunk or breadth of deck if no longitudinals are fitted, in metres, *see* Fig. 6.3.2
s_t = spacing of trunk deck longitudinals, in metres
s_{ts} = spacing of trunk side longitudinals or height of trunk if no longitudinals are fitted, in metres, *see* Fig. 6.3.2, s_{ts} is to be taken as not less than s_t
t_{trd} = thickness of trunk deck plating, in mm
B_{trd} = breadth of trunk deck, in metres
$C_1 = 1 + 3\left(\dfrac{s}{S}\right)^2$, where $\dfrac{s}{S}$ is the ratio of the unstiffened bottom panel under consideration
D_{trd} = depth of ship to trunk deck, measured at the middle of the length L from top of keel to top of the deck beam of the trunk deck at side of trunk, in metres
M = the greater of MS and MH
MH = maximum design hogging bending moment, in tm, *see* Pt 3, Ch 4
MS = maximum design sagging bending moment, in tm, *see* Pt 3, Ch 4

NOTE
The minimum thickness of the tank structure is not to be less than as required by 1.10

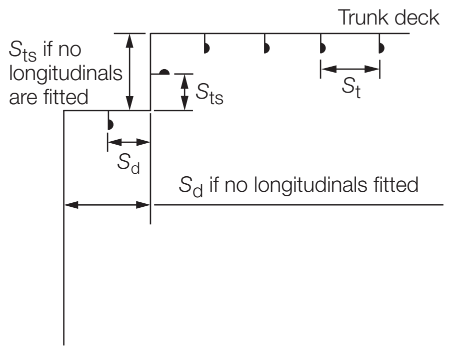


Fig. 6.3.2
Cross-section of longitudinally framed trunk deck tanker

3.11.3 For details regarding the accessibility and the standard required width of the double skin on Type N tankers reference is made to Ch 4,3.7.

■ *Section 4* Hull envelope framing – Transversely framed ships

4.1 General

4.1.1 This Section covers the arrangements and requirements for the transverse hull framing of the midship region of flush deck and trunk deck tankers. The scantlings of floors, bottom girders, frames, stringers and web frames, deck beams, deck girders and pillars are to be in accordance with Table 6.4.1.

4.1.2 Scantlings given in Table 6.4.1 are based on end connections in accordance with Pt 3, Ch 10,3. Where brackets having arm lengths differing from the standard are fitted, the modulus of stiffening member is to be corrected in accordance with Pt 3, Ch 10,3.7.

4.1.3 Outside the midship region the structure is to be scarfed into the fore end and aft end structure as provided for in Pt 3, Ch 5 and Pt 3, Ch 6 so far as applicable.

4.1.4 It is recommended that the bottom of ships regularly resting aground be additionally strengthened to withstand the stresses to which it may be subjected. In such ships scallops or openings (unless reinforced) are not to be made in the lower region of the bottom framing.

4.2 Floors

4.2.1 Plate floors are to be fitted at every frame. The upper edge of the floors is to be suitably stiffened whilst adequate anti-tripping arrangements are to be provided.

4.2.2 The floors are to be provided with sufficient openings to obtain a good flow of cargo to the suction pipes in the tank. In way of large openings additional stiffening may be required. If floors are of scalloped construction, scallops are not to be made in way of the bilge, near longitudinal bulkheads, centre or side girders, or in way of pillars.

4.3 Centreline girder

4.3.1 When the spacing between longitudinal bulkheads in ships without a centreline bulkhead exceeds 5 m, a centreline girder is to be fitted. When the spacing between the longitudinal bulkheads is 5 m or less, an intercostal docking bar is to be fitted at the centreline.

4.4 Side girder

4.4.1 In ships with a centreline bulkhead only and a breadth, *B*, exceeding 12 m, a side girder is to be fitted port and starboard at about $1/4$ *B* from the centreline bulkhead. In ships with two longitudinal bulkheads, where the spacing between the centreline of the girder and the longitudinal bulkheads exceeds 6 m, a side girder is to be fitted port and starboard.

4.5 Side frames, stringers and web frames

4.5.1 Side frames are to be fitted at every frame and are to be connected top and bottom, *see* 4.1.2.

4.5.2 Stringers may be taken into account into the calculation of the frames provided the stringers are fully effective and properly connected to the supporting webframes.

4.6 Deck support – Flush deck tankers

4.6.1 Deck beams are to be fitted at every frame and are to be connected at their ends, *see* 4.1.2.

4.6.2 A deck beam which is cut in way of an opening in the deck, is to be connected to efficient carlings.

4.6.3 For support of deck beams, deck girders may be fitted in conjunction with widely spaced pillars or web beams.

4.6.4 Tubular pillars or other hollow pillars are not to be used. The pillars are to be bracketed top and bottom. The sizes of brackets and welding are to take account of the maximum tensile force in the pillar when the tank is under internal pressure. The floor in way of the pillar heel is to be connected to the adjacent floors by an intercostal girder if not already in line with a Rule side girder.

4.7 Deck support – Trunk deck tankers

4.7.1 Trunk deck beams, trunk side stiffeners and deck beams are to be fitted at every frame and are to be connected at their ends, *see* 4.1.2.

Table 6.4.1 Hull framing – Transversely framed ships

Item	Parameter	Requirement
Floors	Modulus Web thickness	$Z = 6{,}6s\, l_f^2\, h_b$ cm^3 $d_f \geq 30B$ mm $t = 0{,}01d_f + 2$ mm
Centre girder	Web depth Web and face plate thickness Face plate width	$d = d_f$ mm $t = 0{,}01d_f = 2$ mm $w = 140s$ mm
Side girders	Scantlings	As centre girder
Side frames in cargo tanks (single skin)	Modulus	$Z = 7s\, l_e^2\, h_g$ cm^3
Side frames in double skin	Modulus	$Z = 6{,}6s\, l_e^2\, h_f$ cm^3
Deck beams	Modulus	$Z = 6{,}6s\, l_e^2\, h_g$ cm^3
Deck girders	Modulus	$Z = (0{,}7 + 0{,}132L_1)\, s\, l_e^2\, h_g$ cm^3 *See* Note 1
Deck beams on trunk deck	Modulus	$Z_{tdb} = 6{,}6s\, l_e^2\, h_g$ cm^3
Trunk side stiffeners and deck beams abreast trunk	Modulus	$Z = Z_{tdb}$ cm^3
Pillars	Cross-sectionl area	$A = 4{,}5 + 0{,}9P$ cm^2
Stringers in cargo tanks (single skin)	Modulus	$Z = 6{,}6l_s^2\, S\, h_g$ cm^3
Stringers in double skin	Modulus	$Z = 6{,}6l_s^2\, S\, h_f$ cm^3
Webs, supporting stringers and girders	Modulus	Z to be determined from calculations using a stress of 103,0 N/mm^2 (10,5 kgf/mm^2) assuming fixed ends, in association with the head, h_g
Plate webs in double skin	Thickness	The greater of: $t = 7$ mm $t = 9s_d$

Symbols

L, B, D, T, S, s, l_e, h_d, Z, I, ρ and t as defined in 1.12.1

- d_f = depth of floor, in mm
- h = the vertical distance from the middle of the effective length of the stiffening member under consideration to the top of the tank, excluding hatchways, in metres
- h_b = the greater of:
  - (a) the depth, D, but need not to be taken greater than T + 0,4 m
  - (b) $h_g - 0{,}4T$ m
- h_f = $h_{de} + h_t$, but not less than 2 m
- h_{de} = the vertical distance at mid-span of the stiffening member under consideration to the deck at side
- h_t = 0 for void spaces or 0,5 m for deeptanks but not less than the actual distance of the top of the overflow above deck
- h_g = $h\rho + h_d + 0{,}2$ m
- h_t = test head as defined in Table 1.7.2 in Pt 3, Ch 1, in metres
- l_f = span of floor being 0,5B in ships with a centreline bulkhead and in ships with two longitudinal bulkheads the spacing of the bulkheads or 0,4B, whichever is the greater, in metres
- l_s = span of stringer, in metres
- D_2 = D, but need not be taken greater than T + 0,4 m
- K = 1 for Category 'O' ships
- K = 0,75 for Category 'T' ships
- L_1 = L, but is to be not less than 50 m, nor more than 100 m
- P = load supported by the pillar, in tonne-f
- s_d = stiffener spacing or width of double skin whichever is the smaller
- Z_b = section modulus of trunk deck transverses, in cm^3
- Z_{tdb} = section modulus of trunk deck beams, in cm^3

NOTES

1. In case the scantlings of longitudinal members result in an appreciable excess in the hull midship section modulus as required by Pt 3, Ch 4, for the ship type concerned, a reduction in the modulus of the relevant members may be applied, provided the permissible combined bending stress and the permissible local bending stress are not exceeded. For permissible stresses, *see* Section 11.
2. The minimum compartment thickness of the tank structure is not to be less than as required by 1.10.

4.7.2 Where beams are cut in way of openings, the requirements of 4.6.2 are to be complied with.

4.7.3 Arrangements for support of deck beams are to comply with the requirements of 4.6.3 and 4.6.4.

4.8 Double skin arrangement

4.8.1 The scantlings of the structure in the double skin are to be in accordance with Table 6.4.1.

4.8.2 Where the inner skin forms the boundary of cargo tanks, the scantlings of stiffening members are to comply with the requirements of Section 7. Otherwise, the scantlings of stiffening members of the inner skin are to comply with the requirements for deep tanks or watertight bulkheads, as applicable, *see* Pt 3, Ch 7.

4.8.3 For details regarding the accessibility and the standard required width of the double skin on Type C tankers, reference is made to Ch 4,3.6. Requirements are also given for strengthening the double skin in cases where the width is reduced to the minimum value as allowed by the ADN(R). In that case the requirements for reinforcing the sideshell structure by means of additional stringers is also to be complied with.

4.8.4 For details regarding the accessibility and the standard required width of the double skin on Type N tankers, reference is made to Ch 6,3.7.

4.8.5 On type C tankers, profiles or struts connecting structural members of the sideshell with structural members on the longitudinal bulkhead are not allowed.

4.9 Double bottom arrangements

4.9.1 The scantlings of the structure in the double bottom are to be in accordance with Table 6.4.2.

Table 6.4.2 Double bottom (transverse framing)

Item	Parameter	Requirement
(1) Double bottom at centreline	Minimum depth	d_f = 650 mm
(2) Centre girder and side girder	Thickness	t = $0{,}01d_f + 1$ mm
(3) Floors	Thickness	t = $0{,}009d_f + 1$ mm
(4) Watertight floors and floors in line with web frames	Thickness	t = $0{,}009d_f + 1$ mm
For Symbols, *see* Table 6.4.1.		

4.9.2 All parts of double bottom tanks are to be accessible for cleaning and inspection. The tanks are to be well ventilated. Reference is made to Ch 4,3 with regard to general requirements concerning the minimum double bottom height, accessibility, the minimum size of openings and minimum free distances between structural members for passage and inspection.

4.9.3 Plate floors are to be fitted at every frame and are to be suitably stiffened, especially in way of manholes. Centre and side girders are to be arranged as required by 4.3 and 4.4.

4.9.4 On type C tankers, profiles or struts connecting structural members of the bottomshell with structural members on the bottom of the cargo tank are not allowed.

■ *Section 5*
Hull envelope framing – Longitudinally framed ships

5.1 General

5.1.1 This Section covers the arrangements and requirements for longitudinal hull framing of the midship region of flush deck and trunk deck tankers.

5.1.2 The scantlings given in Table 6.5.1 (*see also* 5.4.1) are based on end connections in accordance with Pt 3, Ch 10,3. Where brackets having arm lengths differing from the standard are fitted, the modulus of stiffening members is to be corrected in accordance with Pt 3, Ch 10,3.7.

5.1.3 Outside the midship region the structure is to be scarfed into the fore end and aft end structure as provided for in Pt 3, Ch 5 and Pt 3, Ch 6 so far as applicable.

5.1.4 It is recommended that the bottom of ships regularly resting aground be additionally strengthened to withstand the stresses to which it may be subjected. In such ships scallops or openings (unless reinforced) are not to be made in the lower region of the bottom framing.

5.2 Bottom centreline girder

5.2.1 For dry-docking purposes, single hull ships without a centreline bulkhead are to be fitted with a centreline girder having the same height and thickness as the bottom transverses and provided with suitable anti-tripping arrangements.

5.2.2 For dry-docking purposes, double hull ships are to be fitted with a centreline girder. Centreline girders in double bottom structures are to be suitably stiffened. For further details and scantlings, *see* 5.6.

Table 6.5.1 Hull framing – Longitudinally framed ships – Secondary structure

Item	Parameter	Requirement (*See* Notes 1 and 2)
Bottom longitudinals single skin	Modulus	$Z = K\,[0{,}34 + 0{,}46h_b + L_1\,(0{,}112 - 0{,}009h_b)]\; h_b\, s\, l_e^2$ cm^3
Bottom longitudinals Double skin (*see* Table 6.5.2)	Modulus	$Z = (3{,}95 + 0{,}04L_1) = D_2\, s\, l_e^2$ cm^3
Inner bottom longitudinals Double skin(*see* Table 6.5.2)	Modulus	$Z = 6s\, l_e^2\, h_g$ cm^3
Side longitudinals, single skin	Modulus	$Z = (4 + 0{,}04L_1)\, s\, l_e^2\, h_g$ cm^3
Side longitudinals, double skin	Modulus	$Z = (4{,}6 + 0{,}0342L_1)\, s\, l_e^2\, h_f$ cm^3
Deck, trunkside and trunk deck longitudinals	Modulus Inertia	$Z = [h - 3 + (0{,}18 - 0{,}02h_g)\, L_1]\, h_g\, s\, l_e^2$ cm^3 $I = 2{,}3l_e\, Z$ cm^4

NOTES
1. In case the scantlings of longitudinal members result in an appreciable excess in the hull midship section modulus as required by Pt 3, Ch 4 for the ship type concerned, a reduction in the relevant members may be applied, provided the permissible combined bending stress and the permissible local bending stress are not exceeded. For permissible stresses, *see* Section 11.
2. The minimum compartment thickness of the tank structure is not to be less than as required by 1.10.

5.3 Longitudinal framing

5.3.1 Bottom, inner bottom, side shell, deck, trunk side and trunk deck longitudinals are to comply with the requirements of Table 6.5.1.

5.3.2 On Type C Tankers, where the width of the double skin is less than 1,0 m, the side shell longitudinals are to comply with Ch 4,3.6.

5.3.3 Longitudinals are, generally, to be carried through transverse bulkheads. If they stop at transverse bulkheads, brackets are to be fitted inter-connecting the longitudinals. These are to be arranged such that the cross-sectional area of the longitudinals is maintained, *see* Pt 3, Ch 10,3.3.1(c).

5.3.4 Scallops in longitudinals may not be fitted in way of end connections, crossings with transverses or tripping brackets. Where openings for drainage in longitudinals need to be fitted in way of end connections, etc., reinforcements are required.

5.3.5 Longitudinals which are cut in way of deck openings are to be connected to efficient carlings.

5.4 Primary structure

5.4.1 Longitudinal stiffening members are to be supported by transverses arranged to form ring systems. The spacing of the transverses is not to exceed 3,5 m and their scantlings are to be in accordance with Table 6.5.2. They are to have bracketed end connections, *see* 5.1.2 and 5.4.8.

5.4.2 On certain Type C Tankers, the maximum web-spacing may be further limited, *see* 5.5.4.

5.4.3 For the maximum spacing of floors in double bottoms, *see* 5.6.3.

5.4.4 The depth of transverses is, generally, to be not less than twice the depth of the slots for the longitudinals.

Table 6.5.2 Hull framing – Longitudinally framed ships – Primary structure

Item	Parameter	Requirement
Bottom transverses	Modulus	$Z = 6{,}6S\, l_e^2\, h_b$ cm^3
Side transverses	Modulus	$Z = 10S\, l_e^2\, h_g$ cm^3
Deck and trunk deck transverses	Modulus	The greater of: $Z_b = 6{,}6S\, l_e^2\, h_g$ cm^3 $Z_b = 4{,}3S\, l_e^2\, h_t$ cm^3
Trunk side transverses	Modulus	$Z = Z_b$ cm^3
Plate webs in double skin	Thickness	The greater of: $t = 7$ mm $t = 9\, s_d$

For Symbols, *see* Table 6.4.1

NOTE
The minimum compartment thickness of the tank structure is not to be less than as required by 1.10.

5.4.5 Transverses fitted on the inboard face of longitudinals are to comply with the requirements of Pt 3, Ch 3,3 and associated Fig. 3.3.4.

5.4.6 When the span of transverses exceeds 3 m, tripping brackets connected to the longitudinals are to be fitted about mid-length of the span.

5.4.7 If pillars are fitted to support deck transverses, they are to comply with 4.6.4 and their scantlings are to be in accordance with Table 6.4.1.

5.4.8 As an alternative to bracketed end connections, side shell transverses may be fitted without brackets, provided their section modulus at the intersection with the bottom transverse is at least equal to the modulus of the bottom transverse, and in way of the deck transverse, at least equal to the modulus of the deck transverse. In this case, the respective face bars of the bottom and deck transverse are to be continued beyond their point of intersection and are to be connected to the nearest sideshell and bottom longitudinal in way. In case the facebars do not line up with any longitudinals they are to be sniped in way of the sideshell or bottomplating. The web plate of the bottom and deck transverse is to be stiffened in line with the face of the side transverse, *see also* 7.1.2.

5.5 Double skin arrangements

5.5.1 The scantlings of the secondary structure in the double skin are to be in accordance with Table 6.5.1.

5.5.2 The scantlings of the primary structure in the double skin are to be in accordance with Table 6.5.2.

5.5.3 Where the inner skin forms the boundary of cargo tanks, the scantlings of stiffening members are to comply with the requirements of Section 7. Otherwise, the scantlings of stiffening members of the inner skin are to comply with the requirements for deep tanks or watertight bulkheads, as applicable, *see* Pt 3, Ch 7.

5.5.4 For details regarding the accessibility and the standard required width of the double skin on Type C tankers, reference is made to Ch 4,3.6. Requirements are also given for strengthening the double skin in cases where the width is reduced to the minimum value as allowed by the ADN(R). In that case the requirements for reinforcing sideshell structure by means of strengthened sideshell longitudinals in association with a maximum web frame spacing of 1.80 m is also to be complied with.

5.5.5 For details regarding the accessibility and the standard required width of the double skin on Type N tankers, reference is made to Ch 4,3.7.

5.6 Double bottom arrangements

5.6.1 The scantlings of the structure in the double bottom are to be in accordance with Table 6.5.3.

Table 6.5.3 Double bottom (longitudinal framing)

Location	Scantlings	Requirements
(1) Double bottom of centreline	Minimum depth	d_f = 650 mm
(2) Centre girder and side girder	Thickness	t = $0{,}01 d_f + 1$ mm
(3) Floors, watertight floors and floors in line with web frames	Thickness	t = $0{,}009 d_f + 2$ mm
For Symbols, *see* Table 6.4.1.		

5.6.2 All parts of double bottom tanks are to be accessible for cleaning and inspection. The tanks are to be well ventilated. Reference is made to Ch 4,3.6 with regard to general requirements concerning the minimum double bottom height, accessibility, the minimum size of openings and minimum free distances between structural members for passage and inspection.

5.6.3 A centreline girder is to be fitted as required by 5.2. Floors are to be fitted at a spacing not exceeding 2,5 m. Vertical stiffeners having a depth not less than 50 mm are to be fitted to the floors at every fourth longitudinal. Additional stiffening is to be fitted in way of manholes. Where the spacing of the floors exceeds 2,0 m brackets are to be fitted midway between the floors on either side of the centreline girder and at the margins of the double bottom, extending in each case to the nearest bottom and inner bottom longitudinals. The free edges of the brackets are to be suitably stiffened.

■ *Section 6* Hull envelope framing – Combination system

6.1 General

6.1.1 This Section covers the arrangements and requirements for the hull framing of the midship region of flush deck and trunk deck tankers according to the combination system (shell transverse and bottom and deck longitudinal framing).

6.1.2 The scantlings are based on end connections in accordance with Pt 3, Ch 10,3. Where brackets having arm lengths differing from the standard are fitted, the modulus of stiffening members is to be corrected in accordance with Pt 3, Ch 10,3.7.

6.1.3 Outside the midship region the structure is to be scarfed into the fore end and aft end structure as provided for in Pt 3, Ch 5 and Pt 3, Ch 6 so far as applicable.

6.1.4 It is recommended that the bottom of ships regularly resting aground be additionally strengthened to withstand the stresses to which it may be subjected.

6.2 Bottom centreline girder

6.2.1 A bottom centreline girder is to be fitted if required by 5.2.1.

6.3 Bottom, deck and trunk longitudinals

6.3.1 Longitudinals are to comply with the relevant requirements of 5.1 and 5.3.

6.4 Bottom, deck, trunk deck and trunk side transverses

6.4.1 Transverses are to comply with the relevant requirements of 5.4. In single hull ships they are to be connected to reinforced side frames, *see* 6.5.3. If the shell and longitudinal bulkhead(s) are fitted with a system of stringers and webs, they are to be connected to webframes, *see* 6.5.1.

6.5 Side frames, stringers and web frames

6.5.1 Side frames, stringers and web frames are to comply with the relevant requirements of 4.5. Their scantlings are to be in accordance with Table 6.4.1.

6.5.2 Side frames are to be fitted with end brackets connected to the outboard longitudinals. When, however, the frames are carried through the bilge radius they may be directly connected to the outboard bottom longitudinal.

6.5.3 In single hull ships, the section modulus of side frames in way of bottom and deck transverses is to be increased by 100 per cent.

6.5.4 If a system of stringers and web frames is fitted, the web frames are to be located in way of, and connected to, bottom and deck transverses.

6.6 Double skin arrangements

6.6.1 The arrangements and scantlings of the double skin are to be in accordance with 4.8 or 5.5, as applicable.

6.7 Double bottom arrangements

6.7.1 The arrangements and scantlings of the double bottom are to be in accordance with 4.9 or 5.6, as applicable. The brackets required to be fitted by 5.6.3 at the margins may require to be fitted at every frame.

■ Section 7
Longitudinal and transverse bulkheads of integral cargo tanks

7.1 General

7.1.1 This Section covers the arrangements and requirements for plane and corrugated longitudinal and transverse bulkheads. The thickness of plating and the scantlings of vertical and horizontal stiffeners, stringers, webs and transverses and of corrugated bulkheads are to be in accordance with Table 6.7.1.

Table 6.7.1 Scantlings of plane and corrugated transverse and longitudinal bulkheads of integral cargo tanks

Item	Parameter	Requirement
Plating	Thickness	Plane bulkheads $t = 4s\sqrt{h_g} + K_c$ mm Corrugated bulkheads $t = 4w\sqrt{h_g} + K_c$ mm
Stiffeners	Modulus	$Z = 6s\, l_e^2\, h_g$
Corrugations *See* Note 2	Modulus Inertia	$Z = 7{,}5s\, l_e^2\, h_g$ $I = 3{,}2 l_e\, Z$ cm^4
Stringers and webs supporting stiffeners	Modulus	$Z = 6{,}6s\, l_e^2\, h_g$
Webs supporting stiffeners	Modulus	Z is to be determined from calculations using a stress of 124 N/mm^2 (12,60 kgf/mm^2) assuming fixed ends, in association with the head, h_g

Symbols

Z, I, S, t, s, l_e, ρ and h_d as defined in 1.12.1

h = load height, in metres, measured vertically as follows:
(a) for plating, the distance from the lower edge of the plate to the top of the tank
(b) for stiffening members, the distance from the middle of the effective length to the top of the tank

h_g = $h\rho + h_d + 0{,}2$ m

w = width of flange (b) or web (c), in metres, whichever is the greater, *see* Fig. 3.3.3 in Pt 3, Ch 3,3

K_c = as defined in Table 6.7.2

NOTES
1. The minimum compartment thickness of the tank structure is not to be less than as required by 1.10.
2. The required section modulus of corrugations is based on a fully clamped connection at the lower end and a simple support at the upper end of the bulkhead. Other arrangements will receive special consideration.

7.1.2 The scantlings given in Table 6.7.1 are based on end connections in accordance with Pt 3, Ch 10,3. Where brackets having arm lengths differing from the standard are fitted, the modulus of the stiffening member is to be corrected as indicated in Pt 3, Ch 10,3.7. In tankers of types C and N Closed, all bulkhead stiffeners are to have at least Type I end connections.

7.1.3 Longitudinals are, generally, to be carried through transverse bulkheads. If they stop at transverse bulkheads, brackets are to be fitted interconnecting the longitudinals. These are to be arranged such that the cross-sectional area of the longitudinals is maintained, *see* Pt 3, Ch 10,3.3.1(c).

7.1.4 When the ship is longitudinally framed in deck and bottom, the vertical stiffeners on transverse bulkheads are to be in line with the deck and bottom longitudinals.

7.1.5 Scallops in stiffeners may not be fitted in way of end connections, crossings with primary members and tripping brackets.

7.1.6 The depth of primary members is generally to be not less than twice the depth of the slots for the stiffening members.

7.2 Stainless steel

7.2.1 The material is to comply with the requirements of 1.9.

7.2.2 The thickness of plating forming boundaries of cargo tanks is to be in accordance with the requirements given in Table 6.3.1 and 7.1 as applicable. The plate thickness factor, K_c, depends on the position of the material, relative to the designation of the adjacent space. *See* Table 6.7.2.

Table 6.7.2 Values of plate thickness factor K_c for solid stainless steel

Item	Designation of space adjacent to cargo tank having stainless steel boundaries	K_c in mm
1	Cargo tank	1,0
2	Dry space	0,50
3	Weather deck	0,50
4	Water ballast deep tank (coated)	0,50
5	Double bottom ballast tank (coated)	0,75
6	Double bottom dry tank	0,75
7	Integral heating duct	1,0

7.2.3 Where tank boundary plating may be subjected to primary buckling stresses, or is required to form an effective flange of a primary member, it may be necessary to increase the plating thickness for compliance with general buckling aspects.

7.2.4 The thickness of plating is not to be less than the minimum compartment thickness, *see* 1.10.

7.2.5 The section modulus of mild steel stiffeners attached to stainless steel plating is to be based on the actual plating thickness.

7.3 Cofferdam bulkheads

7.3.1 Requirements for the location, arrangement and testing of cofferdams are given in Ch 4,3.

7.3.2 The scantlings of cofferdam bulkheads are to comply with the requirements of 7.1 and 7.2, as applicable.

7.3.3 Cofferdam bulkheads not bounding the cargo tank are to comply with the requirements of Table 6.7.1 using ρ =1,0 and h_d = 1,0 m.

7.4 Stringers and webs

7.4.1 Vertical stiffeners may be supported by an effective system of stringers and webs. The stringers are to be in line with the stringers of the ship's sides, if fitted.

7.4.2 Horizontal stiffeners of longitudinal bulkheads are to be supported by webs which are to form part of the ring system of transverses required by 5.4.1.

7.4.3 Webs fitted on the inboard face of longitudinals are to comply with the requirements of Pt 3, Ch 3,3 and associated Fig. 3.3.4.

■ *Section 8*
Construction of tankers with cargo tanks independent from the ship's structure

8.1 General

8.1.1 This Section covers the requirements for the hull construction of tankers with independent tanks and semi-independent tanks. For relevant cross sections, *see* Fig. 4.1.2 of Chapter 4 whereby the cargo tanks have been designated as 'Type of Cargo Tank 1'. The thickness of the hull envelope plating and the scantlings of structural members are to be equivalent to those given in Chapter 1, except as stated otherwise in this Section.

8.1.2 Tanks may be supported by bearers of substantial construction. The bearers and supporting brackets are to be arranged in line with floors and girders in the bottom structure. Consideration will be given to proposals to fit flat bottom tanks directly on to the top of bottom structure, taking into account structural interaction resulting from different structural stiffnesses.

8.1.3 Chocks and other securing arrangements are to be fitted to avoid unintentional displacement of the tanks caused by accidents such as collision and/or flooding of the holds. The hull structure in way is to be reinforced accordingly. When the cargo in the tanks can be heated, chocking arrangements are to take account of expansion of the tanks.

8.1.4 The space between the tanks and the surrounding ship's structure should be adequate to enable complete inspection of ship and tank structure.

8.2 Midship section modulus calculation

8.2.1 For the calculation of the midship section modulus, *see* Pt 3, Ch 3,3.4. Where the top of semi-independent tanks is continuous within the midship region and efficiently connected to the ship's structure, the plating and longitudinal stiffeners of the top of the tank, and tank side to 0,1*D* m under deck, may be included in the calculation.

8.3 Topside structure

8.3.1 For ships where the cargo tanks are independent and whereby the topside structure is not efficiently connected to the cargo tanks, the scantlings of the topside structure are to comply with the requirements of Ch 1,4. For all other configurations the scantlings are to comply with the requirements of Section 3. Where transverse stiffening is provided in the top of the tanks, their scantlings are to be in accordance with Section 4. Where longitudinal stiffening is provided in the top of the tanks, their scantlings are to be in accordance with Section 5.

8.4 Hull envelope plating

8.4.1 Apart from the requirements set out in 8.3, the hull envelope plating is to be in accordance with Ch 1,5.

8.5 Double skin arrangement

8.5.1 The plating of the inner skin is to comply with the requirements for deep tank or watertight bulkheads, as applicable, *see* Pt 3, Ch 7.

8.5.2 In addition, arrangements and scantlings of the double skin are to be in accordance with 4.8 or 5.5, as applicable.

8.6 Single bottom structure

8.6.1 A transverse or longitudinal framing system may be adopted, but ships with a length, L, of more than 70 m and transverse framing are to have additional longitudinal stiffening fitted at the bottom. The scantlings of floors, transverses and longitudinals are to comply with the requirements of Table 6.8.1. The remaining structural items are to comply with Ch 1,6.

8.6.2 Floors in a transverse framing system are to be fitted at every frame. Transverses in a longitudinal framing system are to be spaced not more than 2,5 m apart. If the depth of floors is to be locally decreased to suit the shape of the tank which is supported by them, the strength of floors and transverses in way is to be maintained. When the loads exerted by the tanks are not evenly distributed, the strength of the bottom structure is to be verified by direct calculation.

8.6.3 On single hull ships, the section modulus of side frames in way of bottom transverses is to be increased by 100 per cent.

8.6.4 A single bottom structure is not allowed on Tankers of Type C.

Table 6.8.1 Single bottom structure of ships with independent cargo tanks

Item	Parameter	Requirement
(1) Floors	Web depth at centreline Web thickness Modulus	$d_w = 40B$ mm $t = 0{,}01d_w + 2{,}5$ mm The greater of: (a) $Z = 7Ts\,B^2$ cm^3 (b) $Z = \left(17{,}5 - \frac{8{,}3b}{B}\right) h_f\, b\, Bs - 5TB^2 s$ cm^3
(2) Transverses	Modulus	The greater of: (a) $Z = 7T\,S\,B^2$ cm^3 (b) $Z = \left(17{,}5 - \frac{8{,}3b}{B}\right) h_f\, b\, Bs - 5T\,B^2\,S$ cm^3 See Notes 1 and 2
(3) Longitudinals	Modulus	$Z = (3{,}95 + 0{,}04L_1)\, D_1\, s\, l_e^2$ cm^3 *See* Notes 1 and 2

Symbols

L, B, D, T, S, s, l_e, Z, ρ and t as defined in 1.12.1
- b = breadth of tank support on the floor, in metres
- d = mean height of the cargo tank, in metres
- d_w = web depth of floor at centreline, in mm
- D_1 = D, but need not be taken greater than T + 0,4 m
- h_f = d, in metres
- L_1 = l, but to be taken not less than 65 m

NOTES
1. Where effective support at the centreline of the ship is provided, the required section modulus of the floors and transverses will be considered on the basis of a reduced effective span.
2. The formulae are based on the assumption that the load from the tanks is evenly distributed over all floors and transverses in way.

8.7 Double bottom structure

8.7.1 A transverse or longitudinal framing system may be adopted, but ships with a length, *L*, exceeding 70 m are generally to be longitudinally framed. The requirements of Ch 1,7 are generally to be complied with. When cargoes of a higher specific gravity than 1,0 tonnes/m^3 are carried or when the load from the tanks is not evenly distributed over the bottom structure, the strength of the bottom structure is also to be verified by direct calculation.

8.7.2 In addition, arrangements of the double bottom are to be in accordance with 4.9 or 5.6, as applicable.

■ *Section 9* Construction of cargo tanks independent from the ship's structure

9.1 General

9.1.1 This Section covers the arrangements and requirements for independent and semi-independent cargo tanks which are designated as:
Tanks of open or closed type for the carriage of non-dangerous liquids and of dangerous liquids of Class 3, 6.1, 8 and 9.

9.1.2 For a possible restriction of the capacity of tanks, *see* Ch 4,3.

9.1.3 If cargo is to be discharged under pressure, the tanks are regarded as pressure tanks.

9.2 Structural requirements

9.2.1 Pressure tanks are to comply with the requirements for pressure vessels, *see* Ship Type in Chapter 5.

9.2.2 Tanks of open or closed type may have plane or corrugated bulkheads and be constructed with stiffening fitted internally or externally, or a combination of the two.

9.2.3 The scantlings and arrangements of open and closed type tanks are to be in accordance with Section 7. However, when the tanks are of the semi-independent type (*see* Fig. 4.1.2 in Chapter 4) the scantlings of the top of the tanks are to be in accordance with the second part of 8.3.1.

9.2.4 The section modulus of stiffening members of wash bulkheads, if fitted, may be 50 per cent of that required for boundary bulkheads in the same position. The ends of stiffeners may be unattached except those which support girders or longitudinal stiffeners of the tank boundary.

■ *Section 10* Miscellaneous

10.1 Hatchways and closing appliances

10.1.1 For requirements in respect of coamings and closing of deck openings, *see* Ch 4,3.3.

■ *Section 11* Direct calculation procedures

11.1 General

11.1.1 This Section contains guidance for direct calculation, information regarding maximum permissible stresses and minimum requirements for structural members included in the hull midship section modulus and for other structural members which do not form part of the hull midship section modulus.

11.1.2 Where direct calculation is adopted as an alternative to scantlings derived by Rule formulae, or for the assessment of scantlings of structural members not covered by the Rules, calculation results are to be submitted for approval together with all data in support of the calculation, i.e. support conditions and applied loads.

11.2 Loads

11.2.1 Load heads to be used in direct calculations to determine the required section moduli of structural members listed in Tables 6.11.1 and 6.11.2, are to be in accordance with Sections 4 to 8, as applicable.

11.3 Permissible stresses

11.3.1 In addition to the permissible stresses given in Pt 3, Ch 4,6, the following stress criteria are to be applied:

(a) For structural members included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in Table 6.11.1.
(b) For structural members not included in the hull section modulus, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in Table 6.11.2.

11.3.2 Where finite plate element calculations are carried out, local peak stresses in excess to those given in 11.3.1 will be specially considered.

11.4 Structural requirements

11.4.1 As a first approximation the structural components may be determined according to the requirements of the preceding Sections of this Chapter.

Table 6.11.1 Maximum permissible stresses in longitudinal continuous members, in N/mm²

Item	Local bending stress, σ_b	Combined bending stress, σ_c *See* Note 1	Shear stress, τ	Equivalent stress, σ_e *See* Note 2
Bottom and deck girders in transversely-framed ships	110	180	85	190
Bottom, deck and side longitudinals	140	180	85	190

NOTES
1. The combined stress, σ_c, is the sum of the stresses due to longitudinal bending and local loading.
2. The equivalent stress, σ_e, is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_c^2 + 3\tau^2}$

Table 6.11.2 Maximum permissible stresses in local members, in N/mm² (kgf/mm²)

Item	Bending stress, σ_b	Shear stress, τ	Equivalent stress, σ_e *See* Note
Floors, bottom transverses, non-continuous bottom girders, side stringers, deck beams, deck transverses and non-continuous deck girders	124 (12,6)	83 (8,5)	177 (18,0)
Side frames	113 (11,5)	83 (8,5)	172 (17,5)
Webs supporting side stringers, side transverses	103 (10,5)	83 (8,5)	167 (17,0)

NOTE
The equivalent stress, σ_e, is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$

11.4.2 In addition to the maximum permissible stresses given in 11.3, the following minimum plating thickness requirements are to be complied with:

(a) The thickness of bottom plating and side shell plating amidships is to be not less than the thickness of shell plating at ends, *see* Pt 3, Ch 5,2.
(b) The thickness of the bilge plating amidships is to be 2 mm more than the bottom plating in way.
(c) The thickness of the deck plating is to be not less than the thickness of deck plating at ends, *see* Pt 3, Ch 5,2, nor less than the minimum compartment thickness, *see* 1.10. Depending on the level of compressive stresses and panel dimensions, additional buckling calculations may be required.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to propelled and non-propelled tankers intended for the carriage in bulk of:

Commodity	*Ship Type*
Fresh water	Water tanker
Wine	Wine tanker
Edible and vegetable oils with a flash point above 100°C	Edible oil tanker

1.1.2 Fresh water, wine, edible and vegetable oils are generally transported in a Type N open tanker having integrated (ADNR Type 2) cargo tanks as shown in Fig. 4.1.2 in Chapter 4. If carriage of the commodities in tanks independent or semi-independent from the ship's structure is required for special reasons (e.g. heating of cargo, stringent requirements for product purity, etc.), a Type N open tanker is required with tanks generally of ADNR Type 1 or 3 as shown in Fig. 4.1.2 in Chapter 4.

1.1.3 The scantlings and arrangements of the ships are to comply with the requirements of Chapter 6 for a Type N Open tanker carrying non-dangerous liquids in bulk so far as applicable or as otherwise specified in this Chapter.

1.2 Ship arrangement

1.2.1 Cofferdams are generally to be fitted at ends of the cargo compartment for cargo purity reasons.

1.2.2 Cargo tanks may not have common boundaries with any other tank.

1.2.3 For preservation of wine, it is recommended that the cargo tanks be so arranged that in the loaded condition the free surface of the cargo is as small as practicable.

1.3 Class notation

1.3.1 Ships complying with the requirements of this Chapter will be eligible to be classed as follows when the requirements for the particular type of ship have been fulfiled:

‘A1 I.W.W. – Water tanker’, or
‘A1 I.W.W. – Wine tanker’, or
‘A1 I.W.W. – Edible oil tanker’, or
‘A1 I.W.W. – Water barge’, or
‘A1 I.W.W. – Wine barge’, or
‘A1 I.W.W. – Edible oil barge’.

1.3.2 Where appropriate, the type of cargo(es) may be included in the class notation.

1.3.3 The Regulations for classification and assignment of class notations are given in Pt 1, Ch 2 to which reference should be made on the Survey Request form.

1.4 Information required

1.4.1 For the information required, *see* Ch 6,1.11. In addition the following are to be applied so far as applicable:

(a) Particulars of coating or lining to be applied on the structure of the cargo tanks and method of application.
(b) List of edible and vegetable oils intended to be carried in the particular 'Edible oil tanker'.
(c) Details of chocking arrangements for independent tanks.
(d) Particulars of heating arrangements if applied in ‘Edible oil tankers’ together with the maximum temperature to which the cargo will be heated.

■ *Section 2* Materials and protection

2.1 General

2.1.1 In addition to the requirements of Ch 4,2 so far as applicable, the internal structure of mild steel cargo tanks is to be protected against corrosion by the application of a suitable coating or lining which is also suitable for preservation of product purity.

■ *Section 3* Longitudinal strength

3.1 General

3.1.1 The longitudinal strength of water tankers, wine tankers and edible oil tankers is to comply with the requirements of Pt 3, Ch 4 and for this purpose these ships are to be considered as Category ‘T’ ships. The requirements of Ch 6,2.1 are also to be applied.

Section

Section 1 General

1.1 Application

1.1.1 This Chapter applies to self-propelled tugs, pusher tugs and launches, defined as follows:

(a) A tug is a ship designed primarily for the towage of other ships, which does not exclude occasional pushing duties, if arranged for this purpose.
(b) A pusher tug is a ship designed for the pushing of other ships.
(c) A launch is a ship designed primarily for the transport of personnel and small quantities of cargo.

1.1.2 The structural requirements of this Chapter are intended to cover ships having a length not exceeding 50 m, a ratio of length to depth not exceeding 18 and a ratio of breadth to depth not exceeding five.

1.1.3 Launches having a speed exceeding 20 km/h may be constructed according to the requirements for fast small craft, incorporated in the *Rules and Regulations for the Classification of Yachts and Small Craft.*

1.1.4 The scantlings of the ship's structure are to be not less than required in Pt 3, Ch 5 and Ch 6 so far as applicable or as specified otherwise in this Chapter.

1.1.5 The remaining requirements of Part 3 are also to be complied with as appropriate to the intended arrangements.

1.2 Structural configuration

1.2.1 This Chapter provides for a basic structural configuration of a, generally, single decked hull with a single bottom, single skin side construction and a transverse or longitudinal framing system.

1.2.2 For pusher tugs and tugs with relatively high engine power having twin or multiple screws, it is recommended that a double skin side construction be adopted and/or to fit continuous longitudinal bulkheads extending as far forward and aft as practicable.

1.3 Hull vibration

1.3.1 Pusher tugs and tugs with their relatively high engine power are liable to experience a high level of vibration and noise. Attention is drawn to the fact that certain National Authorities specify a maximum level of noise. It is therefore recommended that special attention be given to acoustic insulation and to flexible mounting of the deckhouse, etc.

1.4 Class notation

1.4.1 Ships complying with the requirements of this Chapter will be eligible to be classed 'A1 I.W.W. tug', 'A1 I.W.W. pusher tug' or 'A1 I.W.W. launch'.

1.4.2 The Regulations for classification and assignment of class notations are given in Pt 1, Ch 2 to which reference should be made on the survey request form.

1.4.3 Where a ship has been specially designed, modified and/or arranged in accordance with the additional requirements for Zones 2 or 1, for service extension or for navigation in ice, the appropriate class notation will be assigned.

1.5 Information required

1.5.1 For the information required, *see* Pt 3, Ch 1,5. In addition the following are to be supplied:

(a) The maximum pressure head in service on tanks, also details of any tanks interconnected with side tanks.
(b) The pull, which can be exerted on the towline or the push at the push stem.
(c) Arrangements for the stowage of cargo and details of the deck loads.
(d) Details of cranes or masts for the handling of the cargo, if fitted, and their supporting arrangement.
(e) Support structure and foundations of towing equipment.
(f) Skegs, propeller guards and other structures which support the weight of the vessel during dry-docking.

1.5.2 The following supporting documents are to be submitted for information:

(a) Towing arrangements, including lines of action, magnitudes and corresponding points of application of towline pulls on towing equipment.
(b) Details of the breaking strength of the components of the towline system, together with maximum pull and brake holding load, or equivalent, of towing winches where applicable.

1.6 Symbols and definitions

1.6.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, T as defined in Pt 3, Ch 1,6.1

t = thickness of plating, in mm

P_p = maximum designed shaft power of the propulsion machinery installed in the ship, in kW

(H_p = maximum designed shaft power of the propulsion machinery installed in the ship, in shp).

Section 2
Hull envelope plating

2.1 Shell plating

2.1.1 The thickness of bottom and side shell plating is to be as required by Pt 3, Ch 5,2 and Ch 6,4 but for tugs and pusher tugs the thickness is to be not less than:

$$t = 4{,}8 + 0{,}045L + \frac{\sqrt{1{,}36P_p}}{L + 10} \text{ mm}$$

$$\left(t = 4{,}8 + 0{,}045L + \frac{\sqrt{H_p}}{L + 10} \text{ mm}\right)$$

2.1.2 The thickness of the keel plate is to be the same as required for the bottom plating. When, however, there is a rise of floor the thickness of the keel plate is to be increased by 1 mm.

2.1.3 The thickness of the bilge plating for tugs and pusher tugs is to be 1 mm more than the required thickness of the bottom shell plating. The bilge radius is to be at least ten times the thickness of the bilge plating. The bilge plating is to extend at least 100 mm on either side of the radius of the bilge plate. For the extent of bilge plating in the fore and aft direction, *see* Pt 3, Ch 5,2.4.

2.1.4 Efficient and effectively supported fenders are to be fitted at deck level.

2.2 Deck plating

2.2.1 The thickness of deck plating is to be as required by Pt 3, Ch 5,2, but for tugs and pusher tugs the thickness of the deck is to be not less than 5,5 mm.

2.2.2 The deck thickness is to be locally increased in way of winch seatings and crane supports. The increased thickness is to be not less than 8 mm.

Section 3
Hull envelope framing

3.1 Bottom structure

3.1.1 A centreline girder is generally required in ships having a breadth, *B*, or more than 4 m. A side girder, of the same scantlings as the centreline girder is to be fitted on each side of the centreline in ships with a breadth, *B*, of more than 10 m. Engine seating girders are to form an integral part of the bottom girder system.

Section 4
Towing arrangements

4.1 General

4.1.1 Towing bitts, a towing hook or a towing winch are to be fitted on a tug and should normally be situated 5 to 10 per cent of the ship's length abaft amidships, but it is the designer's responsibility that positive vertical and lateral stability in all circumstances is ensured.

4.1.2 Towing hooks and towing winches should have reliable slip arrangements, which facilitate towline release regardless of the angle of heel.

4.2 Deck structure

4.2.1 The deck structure in way of the towing bitt or towing winch is to be suitably strengthened and supported by means of pillars and girders. The scantlings of this deck structure may be determined by direct calculation using the information given in Section 7.

Section 5
Pushing arrangements

5.1 General

5.1.1 Push stems are to be fitted on pusher tugs and are to comply with the requirements given in Pt 3, Ch 5,4.6. It is recommended that ships primarily used for pushing will be equipped with a twin push stem as indicated in Fig. 5.4.2(b) in Pt 3, Ch 5.

5.1.2 Ships constructed for pushing duties are to be equipped with adequate coupling arrangements, such as winches and wires.

5.2 Deck structure

5.2.1 The deck structure in way of winches for coupling wires and under windlasses is to be suitably strengthened.

Section 6
Propulsion systems

6.1 General

6.1.1 When a propulsion system is fitted like 'Voith Schneider', rudder propellers, etc., note should be taken of the manufacturer's recommendations regarding the position of towing bitt or towing winch, the stability of the ship and the position of skegs.

6.1.2 Propulsion systems protruding under the bottom of the ship are to be protected against damage by an effective structure around the propulsion system. The protective structure is to be strong enough to withstand the loads imposed on it by dry-docking.

6.2 Bottom structure

6.2.1 The bottom structure is to be reinforced around large openings arranged for the fitting of the propulsion system. In general, deep floors in association with longitudinal girders are to be fitted, the scantlings of which may be obtained by direct calculation, using maximum permissible stresses given in Section 7.

6.2.2 The protective structure mentioned in 6.1.2 is to be adequately supported.

■ *Section 7* Direct calculation procedures

7.1 General

7.1.1 This Section contains guidance for direct calculations and information regarding maximum permissible stresses for structural members in the deck and bottom.

7.1.2 Where direct calculation is adopted, all data in support of the calculation, i.e. support conditions and loads are to be submitted, together with the calculation.

7.2 Permissible stresses

7.2.1 For local structural members in bottom and deck, the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in Table 6.7.1.

Table 6.7.1 Maximum permissible stresses in local members in bottom and deck, in N/mm^2 (kgf/mm^2)

Item	Bending stress σ_b	Shear stress τ	Equivalent stress σ_e *see* Note
Bottom transverses, bottom girders, deck girders, deck transverses	124 (12,6)	83 (8,5)	177 (18,0)
Deck beams, floors, deck longitudinals, bottom longitudinals	137 (14,0)	83 (8,5)	186 (19,0)

NOTE
The equivalent stress σ_e is to be calculated according to the formula
$\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$

7.3 Design criteria for the bottom structure

7.3.1 The draught of the ship is to be taken as T + 0,4 m.

7.3.2 The horizontal and vertical loads on a protective structure as mentioned in 6.1.2 may be taken as the maximum weight of the ship.

7.4 Design criteria for the deck structure

7.4.1 For the assessment of the deck structure in way of the towing bitt, towing winch or towing hook, the pull in the towing wire used in the calculation is to be taken as 0,8 times the breaking strength of the towing wire, in conjunction with the permissible stresses given in Table 6.7.1.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to propelled passenger ships, with or without sleeping accommodation, having the machinery aft or amidships.

1.1.2 The scantlings and arrangements are to be as required in Chapter 1 as far as applicable and as specified otherwise in this Chapter.

1.1.3 The structural requirements of this Chapter are intended to cover the midship region as defined in Pt 3, Ch 3,2.2 of ships not exceeding 135 m in length, having a ratio of length to depth not exceeding 35 and in general, a ratio of breadth to depth not exceeding five.

1.1.4 The structural requirements forward and aft of the midship region are to comply with Pt 3, Ch 5 and Ch 6 so far as applicable. The remaining requirements of Part 3 are also to be complied with as appropriate to the intended arrangements.

1.1.5 The requirements in this Chapter are based on the following international regulations:

- The Rhine Inspection Regulations of the Central Rhine Commission (CCNR), in particular Chapter 15, concerning special requirements applicable to Passenger Vessels.
- The Directive of the European Parliament and of the Council of 12 December 2006 laying down technical requirements for inland waterway vessels, in particular Chapter 15, concerning special requirements applicable to Passenger Vessels.

1.1.6 Although the contents of this Chapter takes part of the regulations mentioned in 1.1.5 into account, the issue of a Certificate on behalf of the relevant Authorities requires full compliance with these Regulations.

1.1.7 Attention is drawn to other National and International technical and operational requirements of countries where the ship is registered or operating. These requirements are outside classification as defined in these Rules and Regulations but may however be accepted in lieu of the requirements in 1.1.5 as deemed acceptable by LR.

1.1.8 At the request of the owner or builder and as delegated by the competent National Authority as referred to in 1.1.5 and 1.1.7, LR can also issue a Statement of Compliance with specific National or International requirements.

1.2 Ship arrangement – Definitions

1.2.1 For the purpose of this Chapter, the following definitions apply:

(a) ‘bulkhead deck’: the deck to which the required watertight bulkheads are taken and from which the freeboard is measured;

(b) ‘freeboard’: the distance between the plane of maximum draught and a parallel plane passing through the lowest point of the gunwale or, in the absence of a gunwale, the lowest point of the upper edge of the ship’s side;

(c) ‘residual freeboard’: the vertical clearance available, in the event of the vessel heeling over, between the water level and the upper surface of the deck at the lowest point of the immersed side or, if there is no deck, the lowest point of the upper surface of the fixed ship’s side;

(d) ‘margin line’: an imaginary line drawn on the side plating not less than 10 cm below the bulkhead deck and not less than 10 cm below the lowest non-watertight point of the side plating. If there is no bulkhead deck, a line drawn not less than 10 cm below the lowest line up to which the outer plating is watertight shall be used;

(e) ‘passenger area’: areas on board intended for passengers and enclosed areas such as lounges, offices, shops, hairdressing, salons, drying rooms, laundries, saunas, toilets, washrooms, passageways, connecting passages and stairs not encapsulated by walls;

(f) ‘machinery space’: the space extending from the baseline to the margin line and between the transverse watertight bulkheads containing the main propelling and auxiliary machinery, boilers and coal bunkers if any.

(g ‘permeability of a space’: the percentage of a space which can be occupied by water.

(h) ‘stairwell’: the well of an internal staircase or of a lift;

(j) ‘passageway’: an area intended for the normal movement of persons and goods;

(k) ‘safe area’: the area which is externally bounded by a vertical surface running at a distance of 1/5 of the maximum moulded breadth of the waterline at the maximum design draught parallel to the course of the hull at right angles to the centreline.

1.3 Ship arrangement – Stability and freeboard

1.3.1 The intact and damage stability of the vessel is to be approved by the competent National Authorities in accordance with the regulations as stipulated in 1.1.5.

1.3.2 Proof of sufficient stability may also be furnished by other National or International stability requirements of countries where the ship is registered or operating. These requirements may be accepted in lieu of the requirements in 1.1.5 as deemed acceptable by LR.

1.3.3 At the request of the owner or builder and as delegated by the competent National Authority as referred to in 1.3.1 and 1.3.2 LR can also issue a Statement of Compliance with specific National or International stability requirements.

1.3.4 The freeboard of the vessel shall at least be 300 mm and shall furthermore not be less as required in association with intact and damage stability requirements in accordance with 1.3.1 or 1.3.2.

1.3.5 The maximum draught is to be in compliance with the requirements of 1.3.4 and is to be marked on the ship's sides at about mid-length.

1.4 Ship arrangement – Subdivision and transverse bulkheads

1.4.1 Further to the requirements of Pt 3, Ch 7,1.2 the number and position of bulkheads shall be such that, in the event of flooding, the vessel remains afloat in compliance with 1.3. Every portion of the internal structure which affects the efficiency of the subdivision shall be watertight, and shall be of a design which will maintain the integrity of the subdivision.

1.4.2 The distance between the collision bulkhead and the forward perpendicular shall be at least $0{,}04L_{WL}$ and not more than $0{,}04L_{WL}$ + 2 m.

1.4.3 A transverse bulkhead may be fitted with a bulkhead recess, if all parts of this offset lie within the safe area.

1.4.4 The bulkheads, which are taken into account in the damaged stability calculation according to 1.3 shall be watertight and shall extend up to the bulkhead deck. Where there is no bulkhead deck, these bulkheads shall extend to a height at least 20 cm above the margin line.

1.4.5 The number of openings in the bulkheads referred to above shall be kept to the minimum consistent with the type of construction and normal operation of the vessel. Openings and penetrations shall not have a detrimental effect on the watertight subdivisional aspects of the bulkheads.

1.4.6 Bulkheads according to paragraph 1.4.4 separating the engine rooms from passenger areas or crew and shipboard personnel accommodation shall have no doors.

1.4.7 Where double bottoms are fitted, their height shall be at least 0,60 m, and where a double hull has been fitted, its width shall be at least 0,60 m.

1.4.8 Portholes and windows may be situated below the margin line if they are watertight, cannot be opened, possess sufficient strength and are in compliance with a recognized standard.

1.5 Ship arrangement – Watertight doors and doors

1.5.1 Doors in bulkheads referred to in 1.4.4, and their actuators shall be located in the safe area.

1.5.2 Doors in watertight bulkheads are to be approved by the relevant National Authorities in compliance with 1.1.5 or 1.1.7.

1.5.3 Manually operated doors without remote control in bulkheads referred to in 1.4.4 are permitted only in areas not accessible to passengers. They shall:

(a) remain closed at all times and be opened only temporarily to allow access;
(b) be fitted with suitable devices to enable them to be closed quickly and safely;
(c) display the following notice on both sides of the doors: 'Close door immediately after passing through'.

1.5.4 Doors in bulkheads referred to in 1.4.4 that are open for long periods shall comply with the following requirements:

(a) They shall be capable of being closed from both sides of the bulkhead and from an easily accessible point above the bulkhead deck.
(b) After being closed by remote control the door shall be such that it can be opened again locally and closed safely. Closure shall not be impeded by carpeting, foot rails or other obstructions.

1.5.5 Doors of passenger rooms shall comply with the following requirements:

(a) with the exception of doors leading to connecting corridors, they shall be capable of opening outwards or be constructed as sliding doors.
(b) cabin doors shall be made in such a way that they can also be unlocked from the outside at any time.
(c) powered doors shall be able to be opened easily in the event of failure of the power supply.

1.5.6 Doors intended for use by persons with reduced mobility shall have a minimum clearance of 0,60 m between the inner edge of the doorframe on the side where the lock is located and the adjacent perpendicular wall.

1.5.7 Cold-storage room doors, even when locked, shall be capable of being opened from the inside.

1.6 Ship arrangement – Calculation of the maximum number of passengers

1.6.1 The maximum number of passengers that may be carried is to be assigned by the National Authorities in accordance with the regulations referred to in 1.1.5 and 1.1.7.

1.7 Ship arrangement – Means of escape, corridors and escape routes

1.7.1 Rooms or groups of rooms designed or arranged for 30 or more passengers or including berths for 12 or more passengers shall have at least two exits. On day trip vessels one of these two exits can be replaced by two emergency exits.

1.7.2 For spaces below the freeboard deck, one of the exits may lead through a watertight bulkhead door in accordance with 1.5.4, leading into an adjacent compartment from which the upper deck can be reached directly. The other exit shall lead directly or, if permitted in accordance with 1.7.1 as an emergency exit into the open air or to the bulkhead deck. The foregoing is not applicable to exits of individual cabins.

1.7.3 Exits according to 1.7.1 and 1.7.2 shall be suitably arranged and shall have a clear width of at least 0,80 m and a clear height of at least 2,00 m. For doors of passenger cabins and other small rooms, the clear width may be reduced to 0,70 m.

1.7.4 The width of exits of spaces and combined spaces intended for more than 80 passengers shall be at least 0,01 m per passenger.

1.7.5 Openings for emergency exits shall have a shortest side of at least 0,60 m or a minimum diameter of 0,70 m. Covers shall open in the direction of escape and be shall be marked on both sides as emergency exit.

1.7.6 Exits of rooms intended for use by persons with reduced mobility shall have a clear width of at least 0,90 m. Exits normally used for embarking and disembarking people with reduced mobility shall have a clear width of at least 1,50 m.

1.7.7 Connecting corridors shall have a clear width of at least 0,80 m. If they lead to rooms used by more than 80 passengers their width is to be at least 0,01 m per passenger. The clear height shall be not less than 2,00 m.

1.7.8 Connecting corridors intended for use by persons with reduced mobility shall have a clear width of 1,30 m.

1.7.9 Connecting corridors more than 1,50 m wide shall have handrails on either side.

1.7.10 Where a part of the vessel or a room intended for passengers is served by a single connecting corridor, the clear width of this corridor shall be at least 1,00 m.

1.7.11 Connecting corridors shall be free of steps and shall lead only to open decks, rooms or staircases. Dead ends in connecting corridors shall be not longer than 2 meters.

1.7.12 Stairways, exits and emergency exits shall be so disposed that, in the event of a fire in any given area, the other areas may be evacuated safely.

1.7.13 The route of escape routes shall to evacuation areas such as muster stations shall be as short as possible.

1.7.14 Escape routes shall not lead through engine rooms or galleys.

1.7.15 The fitting of rungs, ladders or similar is not allowed at any point along the escape routes.

1.7.16 Doors in escape routes shall be constructed in such a way as not to reduce the minimum width of the escape route required by 1.7.7 and 1.7.10.

1.7.17 Escape routes and emergency exits shall be clearly marked. The signs shall be lit by the emergency lighting system.

1.8 Ship arrangement – Stairs

1.8.1 Stairs and their landings in the passenger areas shall comply with the following requirements:

(a) they shall be constructed in accordance with recognized standards such as the European standard EN 13056: 2000;
(b) they shall have a clear width of at least 0,80 m or, if they lead to connecting corridors or areas used by more than 80 passengers, at least 0,01 m per passenger;
(c) they shall have a clear width of at least 1,00 m if they provide the only means of access to a space intended for passengers;
(d) where there is not at least one staircase on each side of the vessel in the same zone, they shall lie in the safe area.

1.8.2 Stairs and their landings in the passenger areas intended for use by persons with reduced mobility shall comply with the following requirements:

(a) The gradient of the stairs shall not exceed 38°;
(b) The stairs shall have a clear width of at least 0,90 m;
(c) Spiral staircases are not allowed;
(d) The stairs shall not run in a direction transverse to the vessel;
(e) The handrails of the stairs shall extend approximately 0,30 m beyond the top and bottom of the stairs without restricting traffic routes;
(f) Handrails, front sides of at least the first and the last step as well as the floor coverings at the ends of the stairs shall be colour highlighted.

1.9 Ship arrangement – Bulwarks and openings

1.9.1 Parts of the deck intended for passengers, and which are not enclosed, shall comply with the following requirements:

(a) they shall be surrounded by a fixed bulwark or guard rail at least 1,00 m high or a railing according to the European standard EN 711: 1995, construction type PF, PG or PZ. Bulwarks and railings of decks intended for use by persons with reduced mobility shall be at least 1,10 m high.

1.9.2 Openings and provisions for embarking or disembarking and also openings for loading or unloading shall have a clear width of at least 1,00 m and shall be provided with safety arrangements.

1.9.3 Openings, normally used for the embarking or disembarking of persons with reduced mobility, shall have a clear width of at least 1,50 m.

1.10 Ship arrangement – Life saving appliances

1.10.1 Passenger ships are to be provided with life saving appliances as required by the competent national authorities, *see also* 1.1.5 and 1.1.7.

1.11 Structural configuration

1.11.1 This Chapter provides for a basic structural configuration of a single deck hull with only small access openings, with superstructures or deckhouses over the greater part of the length of the ship and in view of stability requirements, mostly with a double bottom over the full breadth between peak tanks or double bottom wing tanks.

1.11.2 Transverse or longitudinal framing may be adopted. In large ships it is recommended to apply longitudinal framing in the bottom and strength deck. Alternatively transverse framing in bottom and strength deck, with additional longitudinal stiffening may be applied.

1.12 Class notation

1.12.1 Ships complying with the requirements of this Chapter will be eligible to be classed, for example '**A1 I.W.W. passenger ship (River Nile Service)**'.

1.12.2 The Regulations for classification and assignment of class notations are given in Pt 1, Ch 2 to which reference should be made on the Survey request form. If application of stability, buoyancy and other safety criteria of National Authorities is requested and which are considered acceptable to LR, e.g. in view of a particular service area, a suitable notation in this respect will be entered in the *Register Book*.

1.12.3 Where a ship has been specially designed, modified and/or arranged in accordance with the additional requirements for Zones 2 or 1 or for service extension the appropriate class notation will be assigned.

1.13 Information required

1.13.1 For the information required, *see* Pt 3, Ch 1,5. In addition the following information, calculations and documentation are to be supplied:

(a) The maximum pressure head in service on tanks, also details of any tanks interconnected with side tanks, if fitted.

1.13.2 In addition to 1.13.1, the following aspects are to be satisfactory dealt with by the competent national authority, *see also* 1.1.5 and 1.1.7, prior to the issue of the final certificates:

(a) Number of passengers to be carried with calculation of permissible maximum number of passengers.
(b) Intact stability calculations.
(c) Buoyancy and stability calculations for damaged conditions.
(d) Calculation of required minimum freeboard.
(e) Details of life-saving appliances.
(f) Details of fire protection, detection and extinction.

1.14 Symbols and definitions

1.14.1 The following symbols and definitions are applicable to this Chapter unless otherwise stated:

L, B, D, T, C_b for calculation of scantlings, as defined in Pt 3, Ch 1,6.1

l = overall length of stiffening member, in metres, *see* Pt 3, Ch 3,3.2
l_e = effective length of stiffening member, in metres, *see* Pt 3, Ch 3,3.3
s = spacing of secondary stiffeners, i.e. frames, beams or stiffeners, in metres
t = thickness of plating, in mm
I = inertia of stiffening member, in cm^4, *see* Pt 3, Ch 3,3.2
S = spacing or mean spacing of primary members, i.e. girders, transverses, webs, etc., in metres
Z = section modulus of stiffening member, in cm^3, *see* Pt 3, Ch 3,3.2.

■ *Section 2* Materials and protection

2.1 Ceiling on single bottom

2.1.1 Where parts of the spaces below the upper deck with single bottom are intended to be used for storage purposes, efficient ceiling based on the actual loading is to be fitted.

■ *Section 3* Longitudinal strength

3.1 General

3.1.1 For the assessment of the required longitudinal strength which is to be maintained over the midship region, design bending moments are to be calculated. The design bending moments, sagging and hogging, are the maximum moments occurring when the ship is in any condition indicated in 3.1.5 and are to be calculated and verified for ships of a length, L, of more than 40 m and for all ships of unusual type.

3.1.2 The design bending moments are to be determined by direct calculation.

3.1.3 For ships with machinery aft, as a value for assessment of required midship section modulus, the bending moment may be taken as:

$$0{,}044\ (1 - 0{,}86C_b)\ L^2\ B\ T \quad \text{tonne-f m, (hogging)}$$

where

L, B, T and C_b are as defined in 1.14.1

but this value is to be verified by direct calculation for ships having a length, L, of 65 m and above.

3.1.4 For maximum permissible stresses, *see* Pt 3, Ch 4,6.

3.1.5 The following loading conditions for determination of design bending moments are to be covered:

(a) Departure condition:
Ship completely equipped, fresh water, fuel and lubricating oil tanks full, the maximum allowed number of passengers, crew and stores on board and ballast tanks partly or completely filled in accordance with the actual condition.

(b) Arrival condition:
Ship completely equipped, fresh water, fuel and lubricating oil tanks 95 per cent empty and ballast tanks partly or completely filled in accordance with actual condition.

(c) Any condition of the ship giving higher values of bending moments during the voyage.

3.1.6 Where an effective superstructure is fitted (*see* Pt 3, Ch 3,3.4.2), it may be included in calculating the hull section modulus in way. Similarly a deckhouse may be included in calculating the hull section modulus in way, provided the longitudinal bulkheads are at least 0,75B apart, efficiently constructed, well supported, and having a length of at least 0,2L or 10 m whichever is the greater and situated within the midship region.

■ *Section 4*
Shell envelope plating

4.1 General

4.1.1 This Section covers the requirements for the shell envelope plating, viz., keel, bottom, bilge and side shell plating and sheerstrake plating.

4.1.2 The thickness of the shell envelope plating is to be not less than required in Table 9.4.1, but for ships over 40 m in length the thickness of the bottom plating may require to be increased to meet the requirements of Section 3.

4.1.3 For requirements in respect of structural details, *see* Pt 3, Ch 10.

4.2 Keel

4.2.1 The breadth and thickness of the keel plate is to comply with the requirements of Table 9.4.1 and is to be maintained over the full length of the ship.

Table 9.4.1 Shell envelope plating

Item and parameter	Requirements
(1) Plate keel Breadth Thickness	The greater of: $0{,}1B$ m 0,75 m As bottom plating t_b When there is a rise of floor, the thickness is to be increased by 1 mm
(2) Bottom plating Thickness	The greater of: $t_b = (5{,}6 + 0{,}054L)\sqrt{s}$ mm $t_b = 10s$ mm but for ships with a length, L, greater than 40 m, t_b is to be not less than: Longitudinally framed bottom plating: $t_b = 2{,}6\sqrt[3]{\dfrac{MH \times s^2}{B \times D}}$ mm Transversely framed bottom plating: $t_b = 3{,}85\sqrt[3]{\dfrac{MH \times s^2}{B \times D}}$ mm
(3) Bilge plating Thickness	$t = t_b + 2$ mm
(4) Bilge chine bars (a) Round bars Diameter (b) Square bars Side (c) Angle bars Flange thickness	 $3t_b$ mm, but not less than 30 mm $3t_b$ mm, but not less than 30 mm $t = 2t_b$ mm
(5) Side shell plating Thickness	The greater of: $t = (5{,}6 + 0{,}054L)\sqrt{s}$ mm $t = 10s$ mm
(6) Sheerstrake (only to be fitted in absence of efficient steel fender around the ship at deck height) Minimum width Thickness	 $W_{sh} = 0{,}1D$ m t = side shell thickness as required in (5) + 5 mm
Symbols	
L, B, D, S, s and t as defined in 1.14.1 t_b = thickness of bottom plating, in mm MH = design hogging bending moment as calculated according to 3.1.3, in tm $C_1 = 1 + 3\left(\dfrac{s}{S}\right)^2$, where $\dfrac{s}{S}$ is the ratio of the unstiffened bottom panel under consideration	

4.3 Bottom plating

4.3.1 The thickness of bottom plating is to comply with the requirements of Table 9.4.1 and is to be maintained over the midship region and may be tapered to the end thickness in the forward and aft region (*see* Pt 3, Ch 5), according to the requirements for taper given in Pt 3, Ch 3,2.5.

4.4 Bilge plating

4.4.1 The thickness of the bilge plating is to be maintained from amidships to well beyond the forward and aft shoulder of the bilge, but at least over the midship region. For definition of shoulder, *see* Pt 3, Ch 5,2.4.2.

4.4.2 The bilge radius is to be at least 10 times the thickness of the bilge plating and the bilge strake is to extend at least 100 mm on either side of the radius.

4.4.3 Square bilges, constructed by solid round, square or externally fitted angle bars (*see* Fig. 9.4.1), are to comply with Table 9.4.1. The bottom plating and side shell plating adjacent to the round, square or angle bars need not be increased above that of the bottom plating or side shell plating in way.

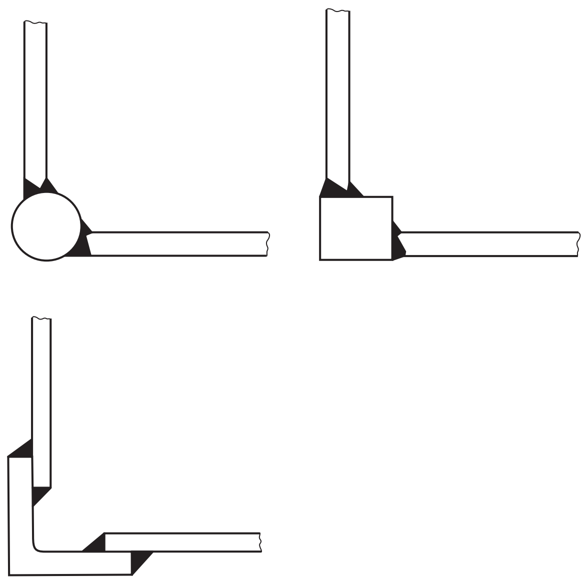


Fig. 9.4.1 Square bilge arrangements

4.5 Side shell plating

4.5.1 The thickness of the side shell plating is to comply with the requirements of Table 9.4.1, which is to be maintained over 0,5*L* amidships and may be tapered to the end thickness in the forward and aft region (*see* Pt 3, Ch 5), according to the requirements for taper given in Pt 3, Ch 3,2.5.

4.6 Sheerstrake

4.6.1 The width and the thickness of the sheerstrake is to comply with the requirements of Table 9.4.1.

4.7 Shell openings

4.7.1 Openings in the shell plating are to have well rounded corners, compensation is generally only required for openings having a width greater than 250 mm. The edges of openings in the shell for side scuttles and windows are to be reinforced on the inside by angle bars of at least 75 mm in height to which the frames of the side scuttles and windows are to be fastened and thus protected. Compensation for the shell plating cut out is only required in the case of large windows. Openings in way of or near the bilge radius are to be circular or elliptical.

■ *Section 5* Deck plating

5.1 General

5.1.1 This Section covers the requirements for the deck plating, which is to be maintained over the midship region and may be tapered to the end thickness in the forward and aft end region (*see* Pt 3, Ch 5), according to the requirements for taper given in Pt 3, Ch 3,2.5.

5.1.2 Where openings are made in the deck plating for access or where a deckhouse is sunk into the deck, the deck plating in way is to be increased in thickness to compensate for the material cut out. No compensation need be fitted if the loss of sectional area has already been taken into account when calculating the actual midship hull section modulus.

5.1.3 Circular openings in the deck plating of a diameter of 150 mm or less need not be compensated, provided they are situated well clear of other openings and the area cut out transversely over the deck does not exceed three per cent of the total cross-sectional area.

5.1.4 Plate panels, in which openings are cut, may have to be adequately stiffened at the edges of the openings.

5.2 Thickness of deck plating

5.2.1 The deck plating thickness is to be not less than as required in Table 9.5.1, but for ships of a length, *L*, of 40 m and over the deck plating may require to be increased to meet the requirements of Section 3.

Table 9.5.1 Deck plating

Item and parameter	Requirements
Deck plating Thickness	The greater of: $t = (5{,}6 + 0{,}039L)\sqrt{s}$ mm $t = 10s$ mm but for ships with a length, *L*, greater than 40 m, *t* is to be not less than: Longitudinally framed deck plating: $t = 0{,}076 \dfrac{M}{B \times D} - \dfrac{a_1}{10B}$ mm Transversely framed deck plating: $t = 0{,}076 \dfrac{M}{B \times D}$ mm
For symbols *see* Table 9.5.2	

5.2.2 The thickness of deck plating within superstructures or deckhouses having a length of at least 0,2*L* or 10 m whichever is the greater and situated within the midship region is to comply with the requirements of Table 9.5.2, but the exposed deck plating at the sides of the deckhouse is to be carried into the deckhouse over a breadth of at least 75 per cent of the frame spacing in way. The exposed deck plating is to be extended into the superstructure or deckhouse at the ends over two frame spaces.

Table 9.5.2 Deck plating within superstructures and deckhouses

Item and parameter	Requirements
Deck plating Thickness	$t = 9s$ mm
Symbols applying to Tables 9.5.1 and 9.5.2	
L, *B*, *D*, *t* and *s* as defined in 1.14.1 a_1 = total area of deck longitudinals, in cm^2 *M* = the greater of *MS* and *MH* *MH* = maximum design hogging bending moment, in tm, *see* Pt 3, Ch 4 *MS* = maximum design sagging bending moment, in tm, *see* Pt 3, Ch 4	

■ *Section 6* Single bottom structure

6.1 General

6.1.1 Requirements are given in this Section for a transversely framed or a longitudinally framed single bottom.

6.1.2 The bottom structure of ships of a length, *L*, less than 25 m is to comply with the requirements of Pt 3, Ch 5 so far as applicable.

6.1.3 The scantlings of structural members of the single bottom of ships having a length of 25 m and over, are to comply with the requirements of Table 9.6.1.

6.2 Girders

6.2.1 A centreline girder is required in ships with a breadth, *B*, of more than 6 m.

6.2.2 A side girder is to be fitted on each side of the centreline in ships with a transversely framed bottom and a breadth, *B*, or more than 12 m.

6.2.3 Where no centreline girder is fitted, adequate support on the centreline must be provided for docking purposes.

6.3 Floors and transverses

6.3.1 Plate floors are to be fitted at every frame.

6.3.2 Transverses are generally to be fitted at a spacing of not more than 3,5 m. However special consideration will be given to proposals for a greater spacing.

6.3.3 In ships having considerable rise of floor the tops of the floors and the transverses are to be made approximately parallel to the rise of floor.

6.3.4 Floors may be cut at the centreline, with the centreline girder web plate continuous, provided the transverse strength of the floor is maintained.

6.3.5 Floors are to be provided with drain holes, sufficient in number and size.

6.3.6 The depth of the transverses is generally to be not less than twice the depth of the slot for the longitudinals.

6.3.7 Longitudinals are generally to be carried through watertight floors and transverse bulkheads. If they stop at the watertight floors and transverse bulkheads, brackets are to be fitted inter-connecting the longitudinals, *see* Pt 3, Ch 10,3.3.1(c).

6.3.8 Scallops in longitudinals may not be fitted in way of end connections, crossings with transverses or tripping brackets.

Table 9.6.1 Transversely and longitudinally framed single bottom

Item	Parameter	Requirements
Longitudinal and transverse framing system		
Centreline girder	Web depth	The lesser of: $d_w = 40B$ mm $d_w = 50l_f$ mm
Centreline girder and side girders	Web and face plate thickness	$t = 0{,}01d_w + 2$ mm
	Width of face plate	$w = 140s$ mm
Transverse framing system		
Floors	Web depth at centreline	The lesser of: $d_f = 40B$ mm $d_f = 50l_f$ mm
	Web thickness	$t = 0{,}01d_w + 2$ mm
	Face plate thickness	$t = \geq t_{web}$ mm
	Face plate width	The greater of: $w = 30l_f$ mm $w = 60$ mm
	Minimum required modulus	$Z = 6{,}6B^2 D_1 s$ cm^3
Longitudinal framing system		
Bottom transverses	Web thickness	$t = 0{,}01d_w + 3$ mm
	Face plate width	The greater of: $w = 30l_f$ mm $w = 60$ mm
	Modulus	$Z = 6{,}6B^2 D_1 S$ cm^3
Bottom longitudinals	Modulus	$Z = (3{,}95 + 0{,}04L_1) D_1 s l_e^2$ cm^3
	Inertia	$I = 2{,}3l_e Z$ cm^4
Symbols applying to Tables 9.6.1 and 9.7.1		
L, B, D, T, s, S, t, I, Z and l_e as defined in 1.14.1 d_f = depth of floor or bottom transverse at centreline, in mm d_w = depth of girder, in mm l_b = the width of the double bottom, in metres, and is normally the breadth of the ship. If longitudinal bulkheads or equivalent supports are provided, an equivalent breadth may be used, but this is to be taken not less than 0,8B l_f = span of floor or transverses which is normally the breadth of the ship measured on top of the floor under consideration, in metres. If longitudinal bulkheads or equivalent floor supports are provided, an equivalent breadth may be used, but this should be taken as not less than 0,4B t_1 = thickness of inner bottom plating or bottom plating whichever is the lesser, in mm w = width of face plate or member, in mm D_1 = D but need be taken as not greater than T + 0,4 m L_1 = L but is to be taken as not less than 65 m		

■ Section 7
Double bottom structure

7.1 General

7.1.1 Requirements are given in this Section for a transversely framed or a longitudinally framed double bottom.

7.1.2 The scantlings of structural members of the double bottom, transversely or longitudinally framed, are to comply with the requirements of Table 9.7.1.

7.1.3 The depth of the double bottom is to comply with the requirements of Table 9.7.1, but it is recommended that the double bottom be accessible for inspection and surveys.

7.1.4 Provision is to be made for free passage of air and water from all parts of the double bottom compartments to the air pipes and suctions, account being taken of the pumping rates required. Where access openings are cut in the floors and girders, the height of openings should not, in general, exceed 50 per cent of the double bottom depth. Openings in way of ends of floors and girders are to be avoided.

Table 9.7.1 Transversely and longitudinally framed double bottom

Item	Parameter	Requirements
Longitudinal and transverse framing systems		
Double bottom height at centreline	Minimum depth	The greater of: $d_f = 40B$ mm $d_f = \dfrac{12D_1 \times l_b^2}{t_i}$ mm
Centreline and side girders	Web thickness	$t = 0{,}01d_f + 2$ mm
Inner bottom plating	Thickness for dry spaces	$t = 10s$ mm
	Thickness for tanks	The greater of: $t = 12s$ mm $t = 5{,}5$ mm
Transverse framing system		
Plate floors and brackets of bracket floors Bracket floors: bottom frames reverse frames	Web thickness Modulus Modulus	The greater of: $t = 0{,}008d_f + 1{,}5$ mm $t = 5{,}5$ mm $Z = 6{,}6s\,D_1\,l_e^2$ cm^3 $Z = 5{,}6s\,D_1\,l_e^2$ cm^3
Longitudinal framing system		
Plate floors Double bottom longitudinals	Web thickness Modulus	$t = 0{,}009d_f + 1{,}5$ mm $Z = 6sD_1\,l_e^2$ cm^3
For Symbols *see* Table 9.6.1		

7.1.5 Where the double bottom is not continuous over the full breadth of the ship (for example at the centreline to form a pipe recess), the transverse strength of the bottom structure is to be maintained and is to comply with the minimum requirements of this Section.

7.1.6 Where a margin plate is proposed to form a bilge, the thickness of the margin plate is to be 1 mm more than required for the inner bottom plating.

7.2 Girders

7.2.1 A centreline girder is required in ships with a breadth, *B*, of more than 6 m. A side girder is generally to be fitted on each side of the centreline in ships with a transversely framed bottom and a breadth, *B*, of more than 12 m. Proposals to omit the centreline girder and/or side girders will be specially considered, but adequate support must be provided on the centreline for docking purposes.

7.3 Floors

7.3.1 In transversely framed double bottoms, plate floors are to be fitted at every frame. Alternatively, bracket floors may be fitted (*see* Pt 3, Ch 5,3.5), provided plate floors are fitted, spaced not more than 2,5 m apart.

7.3.2 In longitudinally framed double bottoms, floors are to be fitted at a spacing not exceeding 3,5 m. Vertical stiffeners having a depth not less than 50 mm are to be fitted to the floors at every fourth longitudinal. In between the floors, brackets are to be fitted in the double bottom in line with the transverse side frames, connected to the tank top and shell plating and extending to the nearest bottom and inner bottom longitudinal. Midway between floors, brackets are to be fitted on either side of the centreline extending to the nearest bottom and inner bottom longitudinals. Free edges of the brackets are to be suitably stiffened.

7.3.3 Plate floors are also to be arranged under bulkheads and in line with web frames fitted in the side structure.

7.4 Inner bottom plating

7.4.1 The thickness of the inner bottom plating is to comply with the requirements of Table 9.7.1.

7.5 Bottom and inner bottom longitudinals

7.5.1 The scantlings of bottom and inner bottom longitudinals are to comply with the requirements of Tables 9.6.1 and 9.7.1 and are based on end connections in accordance with Pt 3, Ch 10,3.

Section 8
Shell envelope framing

8.1 General

8.1.1 Requirements are given in this Section for both longitudinal and transverse framing systems. Where longitudinal framing is not adopted over the full length of the ship, it is to be efficiently scarfed into the transverse framing system.

8.1.2 The scantlings of side frames in the midship region which are based on end connections in accordance with Pt 3, Ch 10,3, are to comply with the requirements given in Table 9.8.1. Where brackets having arm lengths differing from the standard are fitted, the frame modulus is to be corrected in accordance with Ch 10,3.7.

8.2 Transverse shell framing

8.2.1 When the side frames are supported by an effective system of stringers and web frames the Rule section modulus of the frames (ignoring the stringers) may be reduced by 30 per cent.

8.2.2 Where a combination framing system is adopted (shell transverse and bottom deck longitudinal framing) a transverse ring system is to be arranged in way of the supports of the longitudinal stiffening members. The section modulus of the side frames in way of the bottom and deck transverse is to be increased by 100 per cent, and the end connections are to comply with the requirements of Pt 3, Ch 10,3. Brackets at the top and bottom of the side frames are to be connected to the respective adjacent deck and bottom longitudinals. When the frames are carried through the bilge radius, they may be directly connected to the outboard longitudinal.

8.3 Longitudinal shell framing

8.3.1 Longitudinal stiffening members are to be supported by shell transverses which are to comply with the requirements of Table 9.8.1. End brackets may be omitted if the modulus of the shell transverse at the intersection with the bottom transverse is equal to that of the bottom transverse, and at the intersection with the deck transverse is at least equal to that of the deck transverse. The face bar of the side transverse is to be welded to the face bar of the bottom and deck transverse. The web plate of the bottom and deck transverse is to be stiffened in line with the face bar of the side transverse.

8.3.2 The shell transverses are to form a ring system with bottom and deck transverses.

Table 9.8.1 Shell side frames and longitudinals

Location	Modulus
Clear of tanks Frames	$Z_F = 1{,}2D_1\, s\, (2{,}5H^2 + 0{,}03B^2 + 6)$ cm^3
Side shell longitudinals	$Z_{SL} = 6s\, l_e^2\, h_5 + 4$ cm^3
Side transverses longitudinal framing system	*See* 8.3.1
Side frames of combination system in way of bottom/deck transverse	$Z = 2Z_F$ cm^3
In way of O.F. or water tanks Frames	The greater of: $Z_{TF} = Z_F$ $Z_{TF} = 4{,}3s\, l_e^2\, h_4 + 4$ cm^3
Side shell longitudinals	The greater of: $Z_{TSL} = Z_{SL}$ $Z_{TSL} = 4{,}3s\, l_e^2\, h_4 + 4$ cm^3
Side transverses longitudinal framing system	*See* 8.3.1
Side frames of combination system in way of bottom/deck transverse	$Z = 2Z_{TF}$ cm^3
Symbols	
L, B, s and Z as defined in 1.14.1 l_e = effective length of stiffening member, in metres, *see* Pt 3, Ch 3,3.3 D_1 = D but need be taken as not greater than T + 0,4 m H = vertical framing depth, in metres, from the top edge of floor or tank top, to the deck at side as shown in Fig. 5.4.1 in Pt 3, Ch 5 h_4 = load head, in metres, measured vertically from the middle of the effective length to a point 1 metre above the top of the tank, or to the top of the overflow, whichever is the greater h_5 = load head, in metres, measured vertically from the middle of the effective length to the deck at side or to a point T + 0,4 m above baseline, whichever is the lesser, but to be taken as not less than 1,5 m	

Section 9
Deck structure

9.1 Deck supporting structure

9.1.1 The transverse and longitudinal deck supporting structure is to comply with the requirements of Table 9.9.1.

9.1.2 Deck girders and transverses may be fitted in conjunction with load bearing bulkheads or pillars for support of deck beams or deck longitudinals.

9.1.3 Load bearing bulkheads or webs are to be fitted below the deck in line with web stiffeners supporting erection bulkheads.

Table 9.9.1 Deck supporting structure

Item	Modulus
Transverse deck beams	$Z_{TD} = 4{,}3 s l_e^2 h_1 + 4$ cm^3
Transverse beams in way of crown of tank	$Z_{TDCT} = 4{,}3 s l_e^2 h_2 + 4$ cm^3
Deck longitudinals	$Z_{DL} = 4{,}3 s l_e^2 h_1 + 4$ cm^3
Deck longitudinals in way of crown of tank	$Z_{DLCT} = 4{,}3 s l_e^2 h_2 + 4$ cm^3

Item	Parameter	Requirements
Girders and transverses in dry spaces	Modulus	$Z = 4{,}75 h_1 S l_e^2$ cm^3
	Inertia	$I = 2{,}3 l_e Z$ cm^4
Pillars in dry spaces, *see* Note	Cross sectional area of all types of pillars	$A_p = \dfrac{P}{1{,}26 - 4{,}2 \dfrac{l}{r}}$ cm^2
	Minimum wall thickness of hollow pillars	The greater of: (a) $t = 0{,}033 d_p$ mm for tubular pillars $t = 0{,}056 b$ mm for square pillars (b) $t = 5$ mm

Symbols

L, s, S, Z, I and t as defined in 1.14.1

b = breadth of side of a hollow rectangular pillar, in mm
d_p = mean diameter of tubular pillars, in mm
h_1 = head, in metres, as defined in Pt 3, Ch 3,4
h_2 = load head, in metres, measured vertically from the middle of effective length to a point 1 m above the top of tank, or to top of the overflow, whichever is the greater
l = overall length of pillar, in metres
l_e = effective length of stiffening member, in metres, but is to be taken not less than 3 m
r = least radius of gyration of pillar cross-section, in mm, and may be taken as:

$$r = 10\sqrt{\frac{I_p}{A_p}}$$

A_p = cross-sectional area of pillar, in cm^2
I_p = least moment of inertia of cross-section, in cm^4
P = load supported by the pillar, in tonne-f

NOTE
For deck supporting structure in tanks, *see also* Pt 3, Ch 7.

9.1.4 Effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Tripping brackets or equivalent are to be fitted to the transverse or girder web plates in way of pillars. Where eccentric loads are to be supported, the pillars are to be strengthened for the additional bending moment imposed upon them.

■ *Section 10* **Erections**

10.1 General

10.1.1 Erections are to be constructed, in general, according to the requirements of Pt 3, Ch 8.

10.1.2 Where an erection is fitted complying with 3.1.6 the thickness of the deck plating is to comply with the requirements of Table 9.10.1, but on ships having a length of 40 m and over the thickness may require to be increased to meet the requirements of Section 3.

Table 9.10.1 Deck plating of effective superstructures and deckhouses

Item and parameter	Required
Deck plating Thickness	$t = (5{,}6 + 0{,}030L)\sqrt{s}$ mm
Symbols	
L, t and s as defined in 1.14.1	

10.1.3 The side plating of effective erections is to be well stiffened at ends and efficient scarfing into the main structure is to be arranged.

■ *Section 11* **Direct calculation procedures**

11.1 General

11.1.1 This Section contains guidance for direct calculations, information concerning maximum permissible stresses and minimum requirements for structural members included in the hull midship section modulus and for other structural members which do not form part of the hull midship section modulus.

11.1.2 Where direct calculation is adopted as an alternative to scantlings derived by Rule formulae, or for the assessment of scantlings of structural members not covered by the Rules, all data in support of the calculation, i.e. support conditions and loads, are to be submitted for approval together with the calculation.

11.2 Permissible stresses

11.2.1 In addition to the permissible stresses given in Pt 3, Ch 4,6 the following stress criteria are to be applied:

(a) For structural members included in the hull section modulus the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in Table 9.11.1.

(b) For structural members not included in the hull section modulus the maximum bending stresses, shear stresses and equivalent stresses are not to exceed the values given in Table 9.11.2.

11.3 Structural requirements

11.3.1 As a first approximation the structural components may be determined according to the requirements of the preceding Sections of this Chapter.

11.3.2 In addition to the maximum permissible stresses given in 11.2 the following minimum plating thickness requirements are to be complied with:

(a) The thickness of bottom plating and side shell plating amidships is to be not less than the thickness of shell plating at ends, *see* Pt 3, Ch 5,2.

(b) The thickness of the bilge plating amidships is to be 2 mm more than the bottom plating in way.

(c) The minimum thickness of the deck plating is to be not less than required by Table 5.2.2(1) in Pt 3, Ch 5.

(d) Depending on the level of compressive stresses, additional buckling calculations may be required.

Table 9.11.1 Maximum permissible stresses in longitudinal continuous members, in N/mm^2 (kgf/mm^2)

Item	Local bending stress σ_b	Combined bending stress σ_c *see* Note 1	Shear stress τ	Equivalent stress σ_e *see* Note 2
Bottom girders	108 (11,0)	177 (18,0)	83 (8,5)	188 (19,2)
Bottom longitudinals Inner bottom longitudinals Side shell longitudinals	137 (14,0)	177 (18,0)	83 (8,5)	188 (19,2)

NOTES
1. The combined stress σ_c is the sum of the stresses due to longitudinal bending and local loading.
2. The equivalent stress σ_e is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_c^2 + 3\tau^2}$

Table 9.11.2 Maximum permissible stresses in local members, in N/mm^2 (kgf/mm^2)

Item	Bending stress σ_b	Shear stress τ	Equivalent stress σ_e
Floors, non-continuous girders, bottom and deck, deck transverses, bottom transverses	124 (12,6)	83 (8,5)	177 (18,0)
Frames	113 (11,5)	83 (8,5)	172 (17,5)
Deck beams	137 (14,0)	83 (8,5)	186 (19,0)

NOTE
The equivalent stress σ_e is to be calculated according to the formula $\sigma_e = \sqrt{\sigma_b^2 + 3\tau^2}$

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RULES AND REGULATIONS FOR THE CLASSIFICATION OF INLAND WATERWAYS SHIPS

MAIN AND AUXILIARY MACHINERY

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PART 5

Lloyd's Register

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General Requirements for the Design and Construction of Machinery

Section

■ *Scope*

The Chapters in this Part cover the construction and installation of main propulsion and auxiliary machinery systems, together with their associated equipment, boilers, pressure vessels and pumping and piping arrangements fitted in classed ships.

■ *Section 1* General

1.1 Machinery to be constructed under survey

1.1.1 In ships built under Special Survey, all important units of equipment are to be surveyed at the manufacturer's works. The workmanship is to be to the Surveyor's satisfaction and the Surveyor is to be satisfied that the components are suitable for the intended purpose and duty. Examples of such units are:

- Main propulsion engines, including their associated gearing, flexible couplings, scavenge blowers and superchargers.
- Boilers intended for heating of cargo and/or domestic purposes, having working pressures exceeding 0,34 N/mm^2 and having heating surfaces greater than 4,65 m^2.
- Auxiliary engines of 110 kW and over, which are the source of power for services essential for safety or for the operation of the ship.
- Steering machinery.
- Athwart ship thrust units and Azimuth thrusters of 110 kW and over, their prime movers and control mechanisms.
- All heat exchangers necessary for the operation of main propulsion and essential machinery, e.g. air, water and lubricating oil coolers.
- Air compressors, air receivers and other pressure vessels necessary for the operation of main propulsion and essential machinery.
- Any other unfired pressure vessels for which plans are required to be submitted as detailed in Ch 9,1.6.
- All pumps essential for safety of the ship, e.g. fire and bilge pumps.
- Valves and other components intended for the installation in pressure piping systems having working pressures exceeding 7 bar.
- Alarm and control equipment as detailed in Pt 6, Ch 1.
- Electrical equipment as detailed in Pt 6, Ch 2.

1.2 Survey for classification

1.2.1 The Surveyor is to examine and test the materials and examine the workmanship from the commencement of work until the final test of the machinery under full working conditions. Any defects, etc., are to be indicated as early as possible. On completion, the Surveyor will submit a report and if this is found to be satisfactory by the Committee, a certificate will be granted, and an appropriate notation assigned in accordance with Pt 1, Ch 2.

1.3 Alternative system of inspection

1.3.1 Where items of machinery are manufactured as individual or series produced units, the Committee will be prepared to give consideration to the adoption of a survey procedure based on quality assurance concepts utilizing regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual items.

1.3.2 In order to obtain approval, the requirements of Section 7 are to be complied with.

1.3.3 Where it is proposed to install engines and gears not surveyed at the manufacturer's works, but of a recognized and approved standard type, these items are to be tested under full working conditions after fitting on board. Installation of such machinery is to be carried out in accordance with the relevant requirements of the Rules. This survey will entitle the machinery to the special notation in accordance with Pt 1, Ch 2.

1.4 Departures from the Rules

1.4.1 Where it is proposed to depart from the requirements of the Rules, the Committee will be prepared to give consideration to the circumstances of any special case.

1.4.2 Any novelty in the construction of the machinery, boilers or pressure vessels is to be reported to the Committee.

■ *Section 2* Plans and particulars

2.1 Plans

2.1.1 Before the work is commenced, plans in triplicate of all machinery items, as detailed in the Chapters giving the requirements for individual systems, are to be submitted for consideration. The particulars of the machinery, including power ratings and design calculations, where applicable, necessary to verify the design, are also to be submitted. Any subsequent modifications are subject to approval before being put into operation. It is not necessary for plans and particulars to be submitted for each ship, provided the basic plans for the machinery installation have previously been approved. Any alterations to basic design, materials or manufacturing procedure are to be re-submitted for consideration.

2.2 Materials

2.2.1 The materials used in the construction are to be manufactured and tested in accordance with the requirements of Lloyd's Register's (hereinafter referred to as LR) *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Materials for which provision is not made therein may be accepted, provided that they comply with an approved specification and satisfy such tests as may be considered necessary.

2.2.2 Materials used in the construction of machinery and installation should not be a recognized hazard to personnel. This includes the prohibition of asbestos except in the following applications:

(a) Vanes used in rotary vane compressors and rotary vane pumps.
(b) Watertight joints and linings used for the circulation of fluids when at high temperature (in excess of 350ºC) or pressure (in excess of 7 x 10^6 Pa) there is a risk of fire, corrosion or toxicity.
(c) Supple and flexible thermal insulation assemblies used for temperatures above 1000ºC.

■ *Section 3* Operating conditions

3.1 Availability for operation

3.1.1 The design and arrangements are to be such that the machinery can be started and controlled on board ship, without external aid, so that the operating conditions can be maintained under all circumstances.

3.2 Fuel

3.2.1 The flash point (closed cup test) of oil fuel is to be not less than 55°C, unless specially approved.

3.2.2 Fuels with flash points lower than 55°C, but not less than 43°C, unless specially approved, may be used in ships intended for service restricted to certain geographical limits, where it can be ensured that the temperature of the machinery spaces will always be 10°C below the flash point of the fuel. In such cases, safety precautions and the arrangements for storage and pumping will be specially considered.

3.2.3 The use of fuel having a lower flash point than specified in 3.2.1 and 3.2.2, as applicable, may be permitted provided that such fuel is not stored in any machinery space and the arrangements for the complete installation are specially approved.

3.3 Power ratings

3.3.1 In the Chapters where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are to be derived from the following:

- For main propelling machinery, the maximum shaft power and corresponding revolutions per minute giving the maximum torque for which the machinery is to be classed.
- For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute to be used in service.

3.4 Definitions

3.4.1 Units and formulae included in the Rules, are shown in SI units.

3.4.2 Pressure gauges may be calibrated in bar, where

1 bar = 0,1 N/mm^2.

3.5 Temperature conditions

3.5.1 The rating of main and essential auxiliary machinery is to be suitable for the temperature conditions associated with the geographical limits of the proposed service.

3.6 Power conditions for generator sets

3.6.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see* Pt 6, Ch 2.

3.6.2 Engine builders are to satisfy the Surveyors by tests on individual engines that the above requirements, as applicable, can be complied with, due account being taken of the difference between the temperatures under test conditions and those referred to in 3.5. Alternatively, where it is not practicable to test the engine/generator set as a unit, type tests (e.g. against a brake) representing a particular size and range of engines may be accepted. With oil engines, any fuel stop fitted is to be set to permit the short period overload power of not less than 10 per cent above full rated output (kW) being developed.

3.7 Astern power

3.7.1 Sufficient astern power is to be provided to maintain control of the ship in all normal circumstances.

3.8 Bearings

3.8.1 Roller element bearings are to have an L10 design life of at least 30 000 hours, based upon the design operating conditions. An L10 design life of less than 30 000 hours would be accepted, provided it is proposed in conjunction with the manufacturer's design/maintenance manual.

■ *Section 4* Machinery room arrangements

4.1 Accessibility

4.1.1 Accessibility, for attendance and maintenance purposes, is to be provided for machinery plants.

4.2 Machinery fastenings

4.2.1 Bedplates, thrust seatings and other fastenings are to be of robust construction, and the machinery is to be securely fixed to the ship's structure to the satisfaction of the Surveyor.

4.2.2 Where the machinery is installed on resilient mountings, linear vibration (steady state and transient) is not to exceed the limiting values agreed with the manufacturer of the machinery or those of the resilient mountings. Misalignment arising from such vibration is not to impose excessive loading on machinery components within the system.

4.2.3 The Shipbuilder is to ensure that the vibration levels of flexible pipe connections, shaft couplings and mounts remain within the limits specified by the component manufacturer for the start-stop operation and the natural frequencies of the system. Due account is to be taken of any creep that may be inherent in the mount.

4.2.4 Anti-collision chocks are to be fitted together with positive means to ensure that manufacturers' limits are not exceeded. Suitable means are to be provided to accommodate the propeller thrust.

4.3 Ventilation

4.3.1 All spaces, including engine and cargo pump spaces, where flammable or toxic gases or vapours may accumulate, are to be provided with adequate ventilation under all conditions.

4.3.2 The ventilation of a closed engine room on board of tankers is to be arranged such that with an ambient temperature of 20°C the average temperature of the engine room will not exceed 40°C.

4.4 Fire protection

4.4.1 All surfaces of machinery where the surface temperature may exceed 220°C and where impingement of flammable liquids may occur, are to be effectively shielded to prevent ignition. Where insulation covering these surfaces is oil-absorbing or may permit penetration of oil, the insulation is to be encased in steel or equivalent.

4.5 Means of escape

4.5.1 For means of escape from machinery spaces, *see* Pt 3, Ch 6,7.1 and Pt 6, Ch 3,8.1.5.

4.6 Communications

4.6.1 At least one means of communication is to be provided between the wheelhouse and the engine control station.

■ *Section 5* Propulsion redundancy

5.1 Shaft system and bow thruster

5.1.1 Ships having a length exceeding 110 m shall be fitted with:

- two independent shaft installations, each of the same power and a bow thrusters installation controlled from within the wheelhouse, or
- a single shaft installation together with an independent steerable bow thrust installation controllable from within the wheelhouse capable of propelling the ship by own means, also in the unloaded condition by failure of the main propulsion installation. Plans of the independent steerable bow thrust installations are to be submitted for consideration, *see* Chapter 17.

■ *Section 6* Trials

6.1 Inspection

6.1.1 Tests of components and trials of machinery, as detailed in the Chapters giving the requirements for individual systems, are to be carried out to the satisfaction of the Surveyors.

6.2 Trials

6.2.1 For all types of installation, the trials are to be of sufficient duration, and carried out under normal manoeuvring conditions, to prove the machinery under power. The trials are also to demonstrate that any vibration which may occur, within the operating speed range, is acceptable.

6.2.2 The trials are to include demonstrations of the following:

(a) The adequacy of the starting arrangements to provide the required number of starts of the main engines.
(b) The capability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal conditions, to bring the ship to rest from maximum ahead service speed.

6.2.3 Where controllable pitch propellers are fitted, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern position. Where emergency manual pitch setting facilities are provided, their operation is to be demonstrated to the satisfaction of the Surveyor.

6.2.4 In geared installations, prior to full power trials, the gear teeth are to be suitably coated to demonstrate the contact markings, and on conclusion of the trials all gears are to be opened up sufficiently to permit the Surveyors to make an inspection of the teeth. The marking is to indicate freedom from hard bearing, particularly towards the ends of the teeth, including both ends of each helix, where applicable. The contact is to be not less than that required by Ch 3,4.2 or Ch 3,5.2, as applicable.

6.2.5 Where the ship is provided with supplementary means for manoeuvring or stopping, such as a bow thruster, the effectiveness of such means are to be demonstrated.

6.2.6 All trials are to be to the Surveyor's satisfaction.

■ *Section 7* Quality assurance scheme for machinery

7.1 General

7.1.1 This certification scheme is applicable to both individual and series produced items manufactured under closely controlled conditions and will be restricted to works where the employment of quality control procedures is well established. LR will have to be satisfied that the practices employed will ensure that the quality of finished products is to standards which would be demanded when using traditional survey techniques.

7.1.2 The Committee will consider proposed designs for compliance with LR's Rules or other appropriate requirements and the extent to which the manufacturing processes and control procedure ensure conformity of the product to the design. A comprehensive survey will be made by the Surveyor of the actual operation of the quality control programme and of the adequacy and competence of the staff to implement it.

7.1.3 The procedures and practices of manufacturers which have been granted approval will be kept under review.

7.1.4 Approval by another organization will not be accepted as sufficient evidence that a manufacturer's arrangements comply with LR's requirements.

7.2 Requirements for approval

7.2.1 Details for approval to the requirements of this quality assurance scheme for machinery are contained in Pt 5, Ch 1,6 of the *Rules and Regulations for the Classification of Ships.*

■ *Scope*

The requirements of this Chapter are applicable to oil engines (generally known as diesel engines) for main propulsion and to engines intended for essential auxiliary services. Section 3 is not applicable to auxiliary engines having powers of less than 110 kW.

The requirements for type testing of engines at the manufacturer's works are also included.

Arrangements for dual fuel engines will be specially considered.

■ *Section 1* **Plans and particulars**

1.1 Plans

1.1.1 The following plans and particulars as applicable are to be submitted for consideration:

- Crankshaft assembly plan.
- Crankshaft details plan.
- Thrust shaft.
- Thrust bearing assembly.
- Coupling bolts.
- Counterweights, where attached to crankthrow.
- Main engine holding down arrangement.
- Type and arrangement of crankcase explosion relief valves.
- Arrangement and welding specifications with details of the procedures for fabricated bedplate, crankcases, frames and entablatures. Details of welding consumables, fabrication sequence and heat treatments are to be included.
- Schematic layouts of the following systems:
  Starting air.
  Fuel oil.
  Lubricating oil.
  Cooling water.
  Control and safety.
- Shielding of high pressure fuel pipes.
- Combustion pressure-displacement relationship.
- Crankshaft design data as outlined in Section 3.

1.1.2 The following plans are to be submitted for information:

- Longitudinal and transverse cross-section.
- Cast bedplate, crankcase and frames.
- Cylinder cover, liner and jacket (or engine block).
- Piston assembly.
- Tie rod.
- Connecting rod, piston rod, and crosshead assemblies.
- Camshaft drive and camshaft general arrangement.
- Shielding and insulation of exhaust pipes.
- Details of turbo-chargers, *see* Section 10.
- Operation and service manuals.
- Vibration dampers/detuners and moment compensators.

1.1.3 Material specifications covering the listed components in 1.1.1 and 1.1.2 are to be forwarded together with details of any surface treatments, non-destructive testing and hydraulic tests.

1.1.4 Where considered necessary, Lloyd's Register (hereinafter referred to as 'LR') may require additional documentation to be submitted.

1.1.5 For engine types built under license, it is intended that the above documentation be submitted by the Licensor. Each Licensee is then to submit the following:

- A list, based on the above, of all documents required with the relevant drawing numbers and revision status from both Licensor and Licensee.
- The associated documents where the Licensee proposes design modifications to components. In such cases a statement is to be made confirming the Licensor's acceptance of the proposed changes.

In all cases a complete set of endorsed documents will be required by the Surveyor(s) attending the Licensee's works.

■ *Section 2* Materials

2.1 Crankshaft materials

2.1.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

(a) Carbon and carbon-manganese steel castings – 400 to 550 N/mm^2.
(b) Carbon and carbon-manganese steel forgings (normalized and tempered) – 400 to 600 N/mm^2.
(c) Carbon and carbon-manganese steel forgings (quenched and tempered) – not exceeding 700 N/mm^2.
(d) Alloy steel castings – not exceeding 700 N/mm^2.
(e) Alloy steel forgings – not exceeding 1000 N/mm^2.
(f) Spheroidal or nodular graphite iron castings – 370 to 800 N/mm^2.

2.1.2 Where it is proposed to use alloy castings, micro alloyed or alloy steel forgings or iron castings, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

2.2 Material test and inspections

2.2.1 Components for engines are to be tested as indicated in Table 2.2.1 and in accordance with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2.2 For components of novel design, special consideration will be given to the material test and non-destructive testing requirements.

Table 2.2.1 Test requirements for oil engine components

Component	Material tests	Non-destructive tests	
		Magnetic particle or Liquid penetrant	Ultrasonic
Crankshaft	all	all	all
Steel piston crowns	above 400 mm bore	above 400 mm bore	all
Connecting rods, including bearing caps	all	all	above 400 mm bore
Cylinder liner	above 300 mm bore	–	–
Cylinder cover	above 300 mm bore	above 400 mm bore	all
Steel castings for welded bedplates	all	all	all
Steel forgings for welded bedplates	all	–	–
Plates for welded bedplates, frames and entablatures	all	–	–
Crankcases, welded or cast	all	–	–
Turbo-charger, shaft and rotor	above 300 mm bore	–	–
Steel gear wheels for camshaft drives	above 400 mm bore	above 400 mm bore	–

NOTES
1. For closed-die forged crankshafts, the ultrasonic examination may be confined to the initial production and to subsequent occasional checks.
2. Cylinder covers and liners manufactured from spheroidal or nodular graphite iron castings may not be suitable for ultrasonic NDE, depending upon the grain size and geometry. An alternative NDE procedure is to be agreed with LR.
3. Bore dimensions refer to engine cylinder bores.

Section 3
Design

3.1 Scope

3.1.1 The formulae given in this Section are applicable to solid crankshafts, having a main support bearing adjacent to each crankpin, and are intended to be applied to a single crankthrow analysed by the static determinate method.

3.1.2 Alternative methods, including a fully documented stress analysis, will be specially considered.

3.1.3 Calculations are to be carried out for the maximum continuous power rating for all intended operating conditions.

3.1.4 Designs of crankshafts not included in this scope will be subject to special consideration.

3.2 Information to be submitted

3.2.1 In addition to detailed dimensioned plans, the following information is required to be submitted:

- Engine type – 4SCSA/2SCSA/in line/vee.
- Output power at maximum continuous rating (MCR), in kW.
- Output speed at maximum continuous power, in rpm.
- Maximum cylinder pressure, in bar g.
- Mean indicated pressure, in bar g.
- Cylinder air inlet pressure, in bar g.
- Digitized gas pressure/crank angle cycle for MCR.
- Maximum pressure/speed relationship.
- Compression ratio.
- Vee angle and firing interval (if applicable), in degrees.
- Firing order numbered from driving end, *see* Fig. 2.3.1.
- Cylinder diameter, in mm.
- Piston stroke, in mm.
- Mass of connecting rod (including bearings), in kg.
- Centre of gravity of connecting rod from large end centre, in mm.
- Radius of gyration of connecting rod, in mm.
- Length of connecting rod between bearing centres, in mm.
- Mass of single crankweb (indicate if webs either side of pin are of different mass values), in kg.
- Centre of gravity of crankweb mass from shaft axis, in mm.
- Mass of counterweights fitted (for complete crankshaft) indicate positions fitted, in kg.
- Centre of gravity of counterweights (for complete crankshaft) measured from shaft axis, in mm.
- Mass of piston (including piston rod and crosshead where applicable), in kg.
- Material specification(s).
- Specified minimum UTS, in N/mm^2.
- Specified minimum yield strength, in N/mm^2.
- Method of manufacture.
- Details of fatigue enhancement process (if applicable).

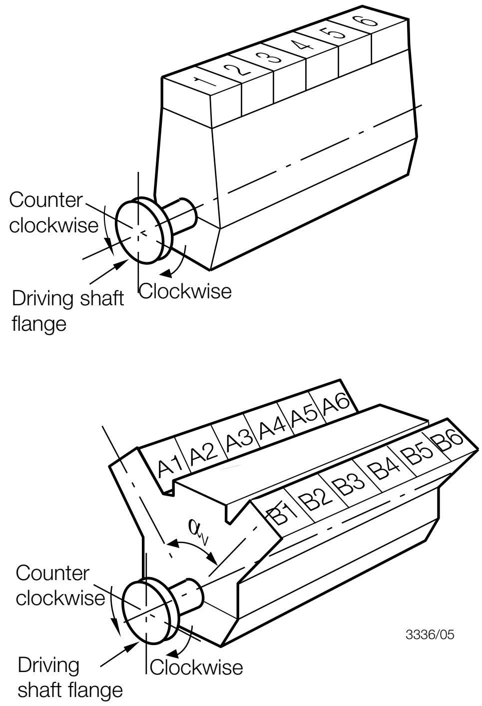


Fig. 2.3.1 Designation of cylinders

3.3 Symbols

3.3.1 For the purposes of this Chapter, the following symbols apply (*see also* Fig. 2.3.2):

h = radial thickness of web, in mm
k_e = bending stress factor
B = transverse breadth of web, in mm
D_p, D_j = outside diameter of pin or main journal, in mm
D_{pi}, D_{ji} = internal diameter of pin or main journal, in mm
F = alternating force at the web centre line, in N
K_1 = fatigue enhancement factor due to manufacturing process
K_2 = fatigue enhancement factor due to surface treatment
M_b = alternating bending moment at web centre line, in N-mm (NOTE: alternating is taken to be $^1/_2$ range value)
M_p, M_j = undercut of fillet radius into web measured from web face, in mm
R_p, R_j = fillet radius at junction of web and pin or journal, in mm
S = stroke, in mm
T = axial thickness of web, in mm
T_a = alternating torsional moment at crankpin or crank journal, in N-mm (NOTE: alternating is taken to be $^1/_2$ range value)
U = pin overlap

$$= \frac{D_p + D_j - S}{2} \text{ mm}$$

α_B = bending stress concentration factor for crankpin
α_T = torsional stress concentration factor for crankpin
β_B = bending stress concentration factor for main journal

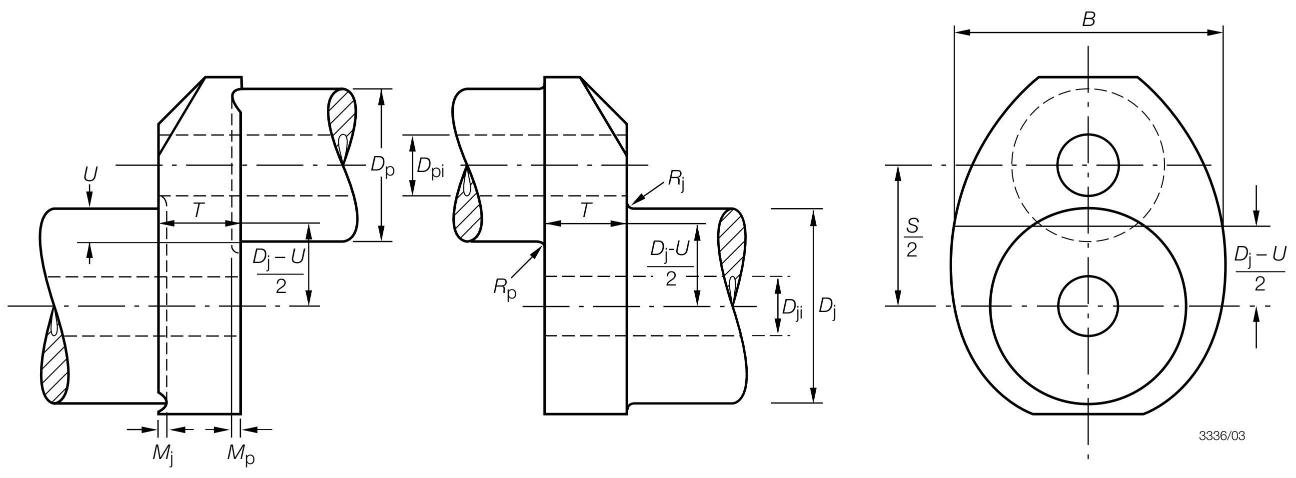


Fig. 2.3.2 Crank dimensions necessary for the calculation of stress concentration factors

β_Q = direct shear stress concentration factor for main journal
β_T = torsional stress concentration factor for main journal
σ_{ax} = alternating axial stress, in N/mm^2
σ_b = alternating bending stress, in N/mm^2
σ_p, σ_j = maximum bending stress in pin and main journal taking into account stress raisers, in N/mm^2
σ_Q = alternating direct stress, in N/mm^2
σ_u = specified minimum UTS of material, in N/mm^2
σ_y = specified minimum yield stress of material, in N/mm^2
τ_a = alternating torsional stress, in N/mm^2
τ_p, τ_j = maximum torsional stress in pin and main journals taking into account stress raisers, in N/mm^2.

3.4 Stress concentration factors

3.4.1 **Geometric factors**. Crankshaft variables to be used in calculating the geometric stress concentrations together with their limits of applicability are shown in Table 2.3.1.

3.4.2 Crankpin stress concentration factors:

Bending

α_B = 2,70 f(ut). f(t). f(b). f(r). f(dp). f(dj). f(rec)

where

f(ut) = $1{,}52 - 4{,}1t + 11{,}2t^2 - 13{,}6t^3 + 6{,}07t^4 - u\,(1{,}86 - 8{,}26t + 18{,}2t^2 - 18{,}5t^3 + 6{,}93t^4) - u^2\,(3{,}84 - 25{,}0t + 70{,}6t^2 - 87{,}0t^3 + 39{,}2t^4)$

f(t) = $2{,}18t^{0{,}717}$

f(b) = $0{,}684 - 0{,}0077b + 0{,}147b^2$

f(r) = $0{,}208r_p^{(-0{,}523)}$

f(dp) = $1 + 0{,}315(d_p) - 1{,}52(d_p)^2 + 2{,}41(d_p)^3$

f(dj) = $1 + 0{,}27d_j - 1{,}02(d_j)^2 + 0{,}531(d_j)^3$

f(rec) = $1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$
valid only between u = –0,5 and 0,5

Torsion

α_T = 0,8 f(ru). f(b). f(t)

where

f(ru) = $r_p^{\,-(0{,}22 + 0{,}1u)}$

f(b) = $7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$

f(t) = $t^{\,(-0{,}145)}$

Table 2.3.1 Crankshaft variables

Variable	Range	
	Lower	Upper
$b = B/D_p$	1,20	2,20
$d_j = D_{ji}/D_p$	0,00	0,80
$d_p = D_{pi}/D_p$	0,00	0,80
$m_j = M_j/D_p$	0,00	r_{jB}
$m_p = M_p/D_p$	0,00	r_p
$r_{jB} = R_j/D_p$	0,03	0,13
$r_{jT} = R_j/D_j$	0,03	0,13
$r_p = R_p/D_p$	0,03	0,13
$t = T/D_p$	0,20	0,80
$u = U/D_p$ *See* Note 2	–0,50	0,70

NOTES
1. Where variables fall outside the range, alternative methods are to be used and full details submitted for consideration.
2. A lower limit of u down to –0,7 is acceptable, but for calculation purposes the limit in this Table applies.

3.4.3 Crank journal stress concentration factors:

Bending

β_B = $2{,}71 f_B(\text{ut}).\ f_B(\text{t}).\ f_B(\text{b}).\ f_B(\text{r}).\ f_B(\text{dj}).\ f_B(\text{dp}).\ f(\text{rec})$

where

$f_B(\text{ut}) = 1{,}2 - 0{,}5t + 0{,}32t^2 - u\,(0{,}80 - 1{,}15t + 0{,}55t^2) - u^2\,(2{,}16 - 2{,}33t + 1{,}26t^2)$

$f_B(\text{t}) = 2{,}24t^{0{,}755}$

$f_B(\text{b}) = 0{,}562 + 0{,}12b + 0{,}118b^2$

$f_B(\text{r}) = 0{,}191 r_{jB}^{(-0{,}557)}$

$f_B(\text{dj}) = 1 - 0{,}644d_j + 1{,}23(d_j)^2$

$f_B(\text{dp}) = 1 - 0{,}19d_p + 0{,}0073(d_p)^2$

$f(\text{rec}) = 1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$
valid only between $u = -0{,}5$ and $0{,}5$

Direct shear

β_Q = $3{,}01 f_Q(\text{u}).\ f_Q(\text{t}).\ f_Q(\text{b}).\ f_Q(\text{r}).\ f_Q(\text{dp}).\ f(\text{rec})$

where

$f_Q(\text{u}) = 1{,}08 + 0{,}88u - 1{,}52(u)^2$

$$f_Q(\text{t}) = \frac{t}{(0{,}0637 + 0{,}937t)}$$

$f_Q(\text{b}) = b - 0{,}5$

$f_Q(\text{r}) = 0{,}533 r_{JB}^{(-0{,}204)}$

$f_Q(\text{dp}) = 1 - 1{,}19d_p + 1{,}74(d_p)^2$

$f(\text{rec}) = 1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$
valid only between $u = -0{,}5$ and $0{,}5$

Torsion

$\beta_T = 0{,}8 f(\text{ru}).\ f(\text{b}).\ f(\text{t})$

where

$f(\text{ru}) = r_{jT}^{-(0{,}22 + 0{,}1u)}$

$f(\text{b}) = 7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$

$f(\text{t}) = t^{(-0{,}145)}$

3.4.4 Where experimental measurements of the stress concentrations are available, these may be used. The full documented analysis of the experimental measurements are to be submitted for consideration.

3.5 Nominal stresses

3.5.1 The nominal alternating bending stress, σ_b, is to be calculated from the maximum and minimum bending moment at the web centre line taking into account all forces being applied to the crank throw in one working cycle with the crank throw simply supported at the mid length of the main journals.

3.5.2 Nominal bending stresses are referred to the web bending modulus.

3.5.3 Nominal alternating bending stress:

$$\sigma_b = \pm \frac{M_b}{Z_{web}} k_e \quad \text{N/mm}^2$$

where

$$Z_{web} = \frac{BT^2}{6} \quad \text{mm}^2$$

k_e = 0,8 for crosshead engines
= 1,0 for trunk piston engines.

3.5.4 The nominal direct shear stress in the web for the purpose of assessing the main journal is to be added algebraically to the bending stress, using the alternating forces which have been used in deriving M_b in 3.5.3.

3.5.5 Nominal stress is referred to the web cross-section area.

3.5.6 Nominal alternating direct shear stress:

$$\sigma_Q = \pm \frac{F}{A_{web}} k_e \quad \text{N/mm}^2$$

where

$A_{web} = BT$ mm^2.

3.5.7 The nominal alternating torsional stress, τ_a, is to be taken into consideration. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted.

3.5.8 The results of torsional vibration calculations for the full dynamic system, carried out in accordance with Ch 6,2.2 are to be submitted.

3.5.9 Nominal alternating torsional stress:

$$\tau_a = \pm \frac{T_a}{Z_T} \quad \text{N/mm}^2$$

where

Z_T = torsional modulus of crankpin and main journal

$$= \pi \frac{D^4 - d^4}{16D} \quad \text{mm}^3$$

D = outside diameter of crankpin or main journal, in mm

d = inside diameter of crankpin or main journal, in mm.

3.5.10 In addition to the bending stress, σ_b, the axial vibratory stress, σ_{ax}, is to be taken into consideration, for crosshead type engines. For trunk type engines, $\sigma_{ax} = 0$. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted. The corresponding crankshaft free-end deflection is also to be stated.

3.6 Maximum stress levels

3.6.1 Crankpin fillet.

- Maximum alternating bending stress:

$\sigma_p = \alpha_B\,(\sigma_b + \sigma_{ax})$ N/mm^2

where

α_B = bending stress concentration (*see* 3.4.2)

- Maximum alternating torsional stress:

$\tau_p = \alpha_T\,\tau_a$ N/mm^2

where

α_T = torsional stress concentration (*see* 3.4.2)

τ_a = nominal alternating torsional stress in crankpin, in N/mm^2.

3.6.2 Crank journal fillet.

- Maximum alternating bending stress:

$\sigma_j = \beta_B (\sigma_b + \sigma_{ax}) + \beta_Q \sigma_Q$ N/mm²

where

β_B = bending stress concentration (*see* 3.4.3)
β_Q = direct stress concentration (*see* 3.4.3)

- Maximum alternating torsional stress:

$\tau_j = \beta_T \tau_a$ N/mm²

where

β_T = torsional stress concentration (*see* 3.4.3)
τ_a = nominal alternating torsional stress in main journal in N/mm².

3.7 Equivalent alternating stress

3.7.1 Equivalent alternating stress of the crankpin, σ_{ep}, or crank journal, σ_{ej}, is defined as:

$$\sigma_{ep}, \sigma_{ej} = \sqrt{(\sigma + 10)^2 + 3\tau^2} \quad \text{N/mm}^2$$

where

$\sigma = \sigma_p$ or σ_j N/mm²
$\tau = \tau_p$ or τ_j N/mm².

3.8 Fatigue strength

3.8.1 The fatigue strength of a crankshaft is based upon the crankpin and crank journal as follows:

$$\sigma_{fp} = K_1 K_2 (0{,}42\sigma_u + 39{,}3)\left(0{,}264 + 1{,}073 D_p^{-0{,}2} + \frac{(785 - \sigma_u)}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_p}}\right)$$

$$\sigma_{fj} = K_1 K_2 (0{,}42\sigma_u + 39{,}3)\left(0{,}264 + 1{,}073 D_j^{-0{,}2} + \frac{(785 - \sigma_u)}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_j}}\right)$$

where

σ_u = UTS of crankpin or crank journal as appropriate
K_1 = fatigue endurance factor appropriate to the manufacturing process
= 1,05 for continuous grain-flow (CGF) or die-forged
= 1,0 for freeform forged
= 0,93 for cast steel
K_2 = fatigue enhancement factor for surface treatment. These treatments are to be applied to the fillet radii.

A value for K_2 will be assigned upon application by the engine designers. Full details of the process, together with the results of full scale fatigue tests will be required to be submitted for consideration. Alternatively, the following values may be taken (surface hardened zone to include fillet radii):

K_2 = 1,15 for induction hardened
= 1,25 for nitrided

Where a value of K_1 or K_2 greater than unity is to be applied, then details of the manufacturing process are to be submitted.

3.9 Acceptability criteria

3.9.1 The acceptability factor, Q, is to be greater than 1,15:

$$Q = \frac{\sigma_f}{\sigma_e} \text{ for crankpin and journal}$$

where

$\sigma_f = \sigma_{fp}$ or σ_{fj}
$\sigma_e = \sigma_{ep}$ or σ_{ej}.

3.10 Oil hole

3.10.1 The junction of the oil hole with the crankpin or main journal surface is to be formed with an adequate radius and smooth surface finish.

3.10.2 Fatigue strength calculations or alternatively fatigue test results may be required to demonstrate acceptability.

3.11 Shrink fit of semi-built crankshafts

3.11.1 For requirements, *see* the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as Rules for Ships), Pt 5, Ch 2,3.11.

■ *Section 4* Construction and welded structures

4.1 Crankcases

4.1.1 Crankcases and their doors are to be of robust construction and the doors are to be securely fastened so that they will not be readily displaced by an explosion.

4.2 Welded joints

4.2.1 Bedplates and major components of engine structures are to be made with a minimum number of welded joints.

4.2.2 Double-welded butt joints are to be adopted wherever possible in view of their superior fatigue strength.

4.2.3 Girder and frame assemblies should, so far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

4.2.4 Steel castings are to be used for parts which would otherwise require complicated weldments.

4.2.5 Care is to be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

4.2.6 Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding can be effected without difficulty and adequate inspection can be carried out. Abrupt changes in plate section are to be avoided and where plates of substantially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

4.2.7 In single plate transverse girders, the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

4.3 Materials and construction

4.3.1 Plates, sections, forgings and castings are to be of welding quality in accordance with the requirements of the Rules for Materials, and with a carbon content generally not exceeding 0,23 per cent. Steels with higher carbon contents may be approved subject to satisfactory results from welding procedure tests.

4.3.2 Plates and weld preparations are to be accurately machined or flame-cut to shape. Flame-cut surfaces are to be cleaned by machining or grinding: if the flame-cut surfaces are smooth, wire brushing may be accepted.

4.3.3 Before welding is commenced the component parts of bedplates and framework are to be accurately fitted and aligned.

4.3.4 The welding is to be carried out in positions free from draughts and is to be downhand (flat) wherever practicable. Welding consumables are to be suitable for the materials being joined. Preheating is to be adopted when heavy plates or sections are welded. The finished welds are to have an even surface and are to be free from undercutting.

4.3.5 Welds attaching bearing housings to the transverse girders are to have a smooth contour and, if necessary, are to be made smooth by grinding.

4.4 Post-weld heat treatment

4.4.1 Bedplates are to be given a stress relieving heat treatment except engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For these types, only the transverse girder assemblies need be stress relieved.

4.4.2 Stress relieving is to be carried out by heating the welded structure uniformly and slowly to a temperature between 580°C and 620°C, holding that temperature for not less than one hour per 25 mm of maximum plate thickness and thereafter allowing the structure to cool slowly in the furnace.

4.5 Inspection

4.5.1 Welded engine structures are to be examined during fabrication, special attention being given to the fit of component parts of major joints prior to welding.

4.5.2 On completion of welding and stress relief heat treatment, all welds are to be examined.

4.5.3 Welds in transverse girder assemblies are to be crack detected by an approved method to the satisfaction of the Surveyor. Other joints are to be similarly tested if required by the Surveyor.

■ *Section 5* Safety arrangements on engines

5.1 Cylinder relief valves

5.1.1 Cylinder relief valves are to be fitted to engines having cylinders over 230 mm bore. The valves are to be loaded to not more than 40 per cent above the designed maximum pressure and are to discharge safely so that no damage occurs.

5.1.2 In the case of auxiliary engines, consideration will be given to the replacement of the relief valve by an efficient warning device of overpressure in the cylinder.

5.1.3 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves.

5.2 Main engine governors

5.2.1 An efficient governor is to be fitted to each main engine so adjusted that the speed does not exceed that for which the engine is to be classed by more than 15 per cent.

5.2.2 Oil engines coupled to electrical generators which are the source of power for main electric propulsion motors are to comply with the requirements for auxiliary engines in respect of governors and overspeed protection devices.

5.3 Auxiliary engine governors

5.3.1 Auxiliary engines intended for driving electric generators are to be fitted with governors which, with fixed setting, are to control the speed within 10 per cent momentary variation and five per cent permanent variation when full load is suddenly taken off or, when after having run on no-load for at least 15 minutes, load is suddenly applied as follows:

(a) For engines with BMEP less than 8 bar, full load, or

(b) For engines with BMEP greater than 8 bar, $\frac{800}{\text{BMEP}}$ per cent, but not less than one-third, of full load, the full load being attained in not more than two additional equal stages as rapidly as possible.

5.3.2 Emergency engines are to comply with 5.3.1 except that the initial load required by 5.3.1(b) is to be not less than the total connected emergency statutory load.

5.3.3 For alternating current installations, the permanent speed variation of the machines intended for parallel operation are to be equal within a tolerance of ±0,5 per cent. Momentary speed variations with load changes in accordance with 5.3.1 are to return to and remain within one per cent of the final steady state speed. This should normally be accomplished within five but in no case more than eight seconds. For quality of power supplies, *see* Pt 6, Ch 2,1.4.3.

5.4 Overspeed protective devices

5.4.1 Each main engine developing 220 kW or over which can be declutched or which drives a controllable (reversible) pitch propeller, also each auxiliary engine developing 220 kW and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

5.4.2 The overspeed protective device, including its driving mechanism, is to be independent of the governor required by 5.2 or 5.3 and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

■ *Section 6* Crankcase safety fitting

NOTE For the purpose of this Section, starting air compressors are to be treated as auxiliary engines

6.1 Relief valves

6.1.1 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices, of an approved type, to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed to open at a pressure not greater than 0,2 bar.

6.1.2 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

6.1.3 The discharge from the valves is to be shielded by flame guard or flame trap to minimize the possibility of danger and damage arising from the emission of flame.

6.2 Number of relief valves

6.2.1 In engines having cylinders not exceeding 200 mm bore and having a crankcase gross volume not exceeding 0,6 m^3, relief valves may be omitted.

6.2.2 In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crankcase. Where the engine has more than eight crank throws an additional valve is to be fitted near the centre of the engine.

6.2.3 In engines having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For engines having 3, 5, 7, 9, etc., crank throws, the number of relief valves is not to be less than 2, 3, 4, 5, etc., respectively.

6.2.4 In engines having cylinders exceeding 300 mm bore at least one valve is to be fitted in way of each main crank throw.

6.2.5 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chaincases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m^3.

6.3 Size of relief valves

6.3.1 The combined free area of the crankcase relief valves fitted on an engine is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

6.3.2 The free area of each relief valve is to be not less than 45 cm^2.

6.3.3 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

6.3.4 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase.

6.4 Vent pipes

6.4.1 Where crankcase vent pipes are fitted, they are to be made as small as practicable to minimize the inrush of air after an explosion. Vents from crankcases of main engines are to be led to a safe position on deck or other approved position.

6.4.2 If provision is made for the extraction of gases from within the crankcase, e.g. for oil mist detection purposes, the vacuum within the crankcase is not to exceed 25 mm of water.

6.4.3 Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crankcases.

6.5 Warning notice

6.5.1 A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

■ *Section 7* Piping

7.1 Oil fuel systems

7.1.1 All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a jacketed piping system capable of containing fuel from a high pressure line failure.

7.1.2 The protection is to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any oil fuel leakage to a collector tank or other approved means fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place.

7.1.3 Oil fuel pipe systems in general, tanks and their fittings are to comply with the requirements of Chapter 12 and Part 3.

7.2 High pressure oil systems

7.2.1 Where flammable oils are used in high pressure systems, the oil pipe lines between the high pressure oil pump and actuating oil pistons are to be protected with a jacketed piping system capable of preventing oil spray from a high-pressure line failure.

7.3 Exhaust systems

7.3.1 Where the surface temperature of the exhaust pipes and silencer may exceed 220ºC, they are to be water cooled or efficiently lagged to minimize the risk of fire and to prevent damage by heat. Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

7.3.2 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the engine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard.

7.3.3 Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economizer, an isolating device is to be provided in each exhaust pipe.

7.4 Starting air pipe systems and safety fittings

7.4.1 In designing the compressed air installation, care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or, alternatively, an air duct from outside the machinery space is to be led to the compressors.

7.4.2 The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

7.4.3 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

7.4.4 Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipelines, drain valves are to be fitted to suitably located drain pots or separators.

7.4.5 The starting air piping system is to be protected against the effects of explosions by providing an isolating non-return valve or equivalent at the starting air supply to each engine.

7.4.6 In direct reversing engines, bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines, at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in engines where the cylinder bore does not exceed 230 mm.

7.4.7 Alternative safety arrangements may be submitted for consideration.

■ *Section 8* Starting arrangements, air compressors and batteries

8.1 Air compressors

8.1.1 Where compressed air is used for starting and manoeuvring purposes, the following arrangements are to be provided as applicable:

(a) **Main engine driven compressor provided**. An additional independently power driven compressor is to be fitted. If this compressor is driven by an auxiliary engine, the engine is to be of a hand or electric started type. Alternatively, other devices of an approved type may be accepted in lieu of the independently driven compressor.

(b) **Main engine driven compressor not provided**. Two independently power driven compressor are to be fitted. If the compressors are driven by auxiliary engines, at least one of the engines is to be of a hand or electric started type.

8.1.2 The air compressors fitted should have a total capacity capable of charging the air receivers within one hour from atmospheric pressure to the pressure sufficient for the number of starts required by 8.2. The capacity of the air compressors is to be approximately equally divided between them.

8.1.3 Power driven compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C in service. A small fusible plug or an alarm device operating at 121°C is to be provided on each compressor to give warning of excessive air temperature.

8.1.4 Each power driven compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube.

8.2 Air receiver capacity

8.2.1 Where the main engine is arranged for air starting, the total air receiver capacity is to be sufficient to provide without replenishment, not less than 12 consecutive starts of the main engine, alternating between ahead and astern if of the reversible type and not less than six consecutive starts if of the non-reversible type. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see* Chapter 9.

8.2.2 For multi-screw installations with one engine per shaft line, the following requirements apply:

(a) For reversing engines, 12 consecutive starts per engine required.

(b) For non reversing engines driven by a CPP installation, six consecutive starts per engine required.

(c) For non reversing engines with reverse reduction gears for fixed or CPP shafting installations, six consecutive starts per engine are required.

8.3 Electric starting

8.3.1 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by 8.2.1 and 8.2.2. In other respects batteries are to comply with the requirements of Pt 6, Ch 2.

8.3.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or be supplied by separate circuits from the main engine batteries when such are provided. Where one of the auxiliary engines only is fitted with an electric starter one battery will be acceptable.

8.3.3 The combined capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

8.3.4 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own monitoring arrangements. Means are to be provided to ensure that the stored energy in the batteries is maintained at a level required to start the engines, as defined in 8.3.1 and 8.3.3.

8.3.5 Where engines are fitted with electric starting batteries, an alarm is to be provided for low battery charge level.

■ *Section 9* Component tests and engine type testing

9.1 Hydraulic tests

9.1.1 In general, items are to be tested by hydraulic pressure as indicated in Table 2.9.1. Where design features are such that modifications to the test requirements shown in Table 2.9.1 are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.

9.2 Engine type testing

9.2.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation.

9.2.2 Guidelines for type testing of engines will be supplied on application.

Table 2.9.1 Test pressures for oil engine components

Item		Test pressure
Fuel injection system	Pump body, pressure side Valve Pipe	The lesser of 1,5*p* or *p* + 295 bar
Cylinder cover, cooling space Cylinder liner, over the whole length of cooling space Piston crown, cooling space (where piston rod seals cooling space, test after assembly)		7,0 bar
Cylinder jacket, cooling space Exhaust valve, cooling space Turbo-charger, cooling space Exhaust pipe, cooling space Coolers, each side Engine driven pumps (oil, water, fuel, bilge)		The greater of 4,0 bar or 1,5*p*
Air compressor, including cylinders, covers, intercoolers and aftercoolers Scavenge pump cylinder		Air side: 1,5*p* Water side: The greater of 4,0 bar or 1,5*p* 4,0 bar

NOTES
1. *p* is the maximum working pressure in the item concerned.
2. Fuel pumps of the jerk or timed pump system are not included.
3. Turbo-charger air coolers need only be tested on the water side.
4. For forged steel cylinder covers alternative testing methods will be specially considered.

9.2.3 An engine type is defined in terms of:
- basic engine data: e.g. bore, stroke;
- working cycle: 2 stroke, 4 stroke;
- cylinder arrangement: in-line, vee;
- cylinder rating;
- fuel supply: e.g. direct, or indirect injection, dual fuel;
- gas exchange: natural aspiration, pressure charging arrangement.

9.2.4 Where an engine type has subsequently proved satisfactory in service with a number of applications a maximum uprating of 10 per cent may be considered without a further complete type test.

9.2.5 A type test will be considered to cover engines of a given design for a range of cylinder numbers in a given cylinder arrangement.

■ *Section 10* **Turbo-chargers**

10.1 Plans and particulars

10.1.1 The following plans and particulars are to be submitted for information:
- Cross sectional plans of the assembled turbo-charger with main dimensions.
- Fully dimensioned plans of the rotor.
- Material particulars with details of welding and surface treatments.
- Turbo-charger operating and test data.
- A selected turbo-charger is to be type tested.

10.2 Type test

10.2.1 A type test is to consist of a hot gas running test of at least one hour duration at the maximum permissible speed and maximum permissible temperature. Following the test the turbo-charger is to be completely dismantled for examination of all parts.

10.2.2 Alternative arrangements will be specially considered.

10.3 Dynamic balancing

10.3.1 All rotors are to be dynamically balanced on final assembly to the Surveyor's satisfaction.

10.4 Overspeed test

10.4.1 All fully bladed rotor sections and impeller/inducer wheels are to be overspeed tested for three minutes at either 20 per cent above the maximum permissible speed at room temperature or 10 per cent above the maximum permissible speed at the normal working temperature.

10.5 Mechanical running test

10.5.1 Turbo-chargers are to be given a mechanical running test of 20 minutes duration at the maximum permissible speed.

10.5.2 Upon application, with details of an historical audit covering previous testing of turbo-chargers manufactured under an approved quality assurance scheme, consideration will be given to confining the test outlined in 10.5.1 to a representative sample of turbochargers.

■ *Cross-references*

The pumping arrangements, including cooling water and lubricating oil systems, are to comply with the requirements of Chapter 12.

Section

■ *Scope*

The requirements of this Chapter, except where otherwise stated, are applicable to oil engine gearing for main propulsion purposes and for oil engine gearing for driving auxiliary machinery which is essential for the safety of the ship or for safety of persons on board where the transmitted powers exceed 220 kW for propulsion drives, and 110 kW for auxiliary drives. In any mesh, the terms ‘pinion’ and ‘wheel’ refer to the smaller and larger gear respectively. Bevel gears will be specially considered on the basis of a conversion to equivalent helical gears. For torsional vibration requirements, *see* Ch 6,2.3.

■ *Section 1* Plans and particulars

1.1 Gearing plans

1.1.1 Particulars of the gearing are to be submitted with the plans for all propulsion gears and for auxiliary gears where the transmitted power exceeds 110 kW, as follows:

- Shaft power and revolution for each pinion.
- Number of teeth in each gear.
- Reference diameters.
- Helix angles at reference diameters.
- Normal pitches of teeth at reference diameters.
- Tip diameters.
- Root diameters.
- Face widths and gaps, where applicable.
- Pressure angles of teeth (normal or transverse) at reference diameters.
- Accuracy grade Q in accordance with ISO 1328 or an equivalent standard.
- Surface texture of tooth flanks and roots.
- Minimum backlash.
- Centre distance.
- Basic rack tooth form.
- Protuberance and final machining allowance.
- Details of post hobbing processes, if any.
- Details of tooth flank corrections, if adopted.
- Case depth for surface-hardened teeth.
- Shrinkage allowance for shrunk-on rims and hubs.
- Type of coupling proposed for oil engine applications.

1.2 Material specifications

1.2.1 Specifications for materials of pinions, pinion sleeves, wheel rims, gear wheels and quill shafts, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval with the plans of gearing.

1.2.2 Where the teeth of a pinion or gear wheel are to be surface hardened, i.e. carburized, nitrided, tufftrided or induction-hardened, the proposed specification and details of the procedure are to be submitted for approval.

■ *Section 2* Materials

2.1 Material properties

2.1.1 In the selection of materials for pinions and wheels, consideration is to be given to their compatibility in operation. Except in the case of low reduction ratios, for gears of through-hardened steels, provision is also to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

2.1.2 Subject to 2.1.1, the specified minimum tensile strength is to be selected within the following limits:

Pinion and pinion sleeves	550 to 1050 N/mm^2
Gear wheels and rims	400 to 850 N/mm^2

A tensile strength range is also to be specified and is not to exceed 120 N/mm^2 when the specified minimum tensile strength is 600 N/mm^2 or less. For higher strength steels, the range is not to exceed 150 N/mm^2.

2.1.3 Unless otherwise agreed, the full specified minimum tensile strength of the core is to be 800 N/mm^2 for induction-hardened or nitrided gearing and 750 N/mm^2 for carburized gearing.

2.1.4 For nitrided gearing, the full depth of the hardened zone is to be not less than 0,5 mm and the hardness is to be not less than 500 Hv for a depth of 0,25 mm.

2.2 Non-destructive tests

2.2.1 An ultrasonic examination is to be carried out on all gear blanks where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm.

2.2.2 Magnetic particle or liquid penetrant examination is to be carried out on all surface-hardened teeth. This examination may also be requested on the finished machined teeth of through-hardened gears.

Section 3
Design

3.1 Symbols

3.1.1 For the purposes of this Chapter, the following symbols apply:

a = centre distance, in mm
b = facewidth, in mm
d = reference diameter, in mm
d_a = tip diameter, in mm
d_{an} = virtual tip diameter, in mm
d_b = base diameter, in mm
d_{bn} = virtual base diameter, in mm
d_{en} = virtual diameter to the highest point of single tooth pair contact, in mm
d_f = root diameter, in mm
d_{fn} = virtual root diameter, in mm
d_n = virtual reference diameter, in mm
d_s = shrink diameter, in mm
d_w = pitch circle diameter, in mm
f_{ma} = tooth flank misalignment due to manufacturing errors, in μm
f_{pb} = maximum base pitch deviation of wheel, in μm
f_{Sh} = tooth flank misalignment due to wheel and pinion deflections, in μm
f_{Sho} = intermediary factor for the determination of f_{Sh}
g_α = length of line of action for external gears, in mm:

$$= 0{,}5\sqrt{(d_{a1}{}^2 - d_{b1}{}^2)} + 0{,}5\sqrt{(d_{a2}{}^2 - d_{b2}{}^2)} - a\sin\alpha_{tw}$$

for internal gears:

$$= 0{,}5\sqrt{(d_{a1}{}^2 - d_{b1}{}^2)} - 0{,}5\sqrt{(d_{a2}{}^2 - d_{b2}{}^2)} + a\sin\alpha_{tw}$$

h = total depth of tooth, in mm
h_{ao} = basic rack addendum of tool, in mm
h_F = bending moment arm for root stress, in mm
m_n = normal module, in mm
n = rev/min of pinion
q = machining allowances, in mm
q_s = notch parameter
q' = intermediary factor for the determination of C_γ

$$u = \text{gear ratio} = \frac{\text{Number of teeth in wheel}}{\text{Number of teeth in pinion}} \geq 1$$

v = linear speed at pitch circle, in m/s
x = addendum modification coefficient
y_α = running in allowance, in μm
y_β = running in allowance, in μm
z = number of teeth
z_n = virtual number of teeth

$$= \frac{z}{\cos^2\beta_b\cos\beta}$$

C_γ = tooth mesh stiffness (mean total mesh stiffness per unit facewidth), in N/mm μm
F_t = nominal tangential tooth load, in N

$$= \frac{P}{nd}\ 19{,}098 \times 10^6$$

F_β = total tooth alignment deviation (maximum value specified), in μm
$F_{\beta x}$ = actual longitudinal tooth flank deviation before running in, in μm
$F_{\beta y}$ = actual longitudinal tooth flank deviation after running in, in μm
HV = Vickers hardness number
K_A = application factor
$K_{F\alpha}$ = transverse load distribution factor
$K_{F\beta}$ = longitudinal load distribution factor
$K_{H\alpha}$ = transverse load distribution factor
$K_{H\beta}$ = longitudinal load distribution factor
K_v = dynamic factor
$K_{v\alpha}$ = dynamic factor for spur gears
$K_{v\beta}$ = dynamic factor for helical gears
K_γ = load sharing factor
P = transmitted power, in kW
P_r = radial pressure at shrinkage surface, in N/mm^2
P_{ro} = protuberance of tool, in mm
Q = accuracy grade from ISO 1328 – 1975
R_a = surface roughness – arithmetical mean deviation (C.L.A.) as determined by an instrument having a minimum wavelength cut-off of 0,8 mm and for a sampling length of 2,5 mm, in μm
S_{pr} = residual undercut left by protuberance in mm
$S_{F\,min}$ = minimum factor of safety for bending stress
S_{Fn} = tooth root chord in the critical section, in mm
$S_{H\,min}$ = minimum factor of safety for Hertzian contact stress
Y_D = design factor
Y_F = tooth form factor
$Y_{R\,rel\,T}$ = relative surface finish factor
Y_S = stress concentration factor
Y_{ST} = stress correction factor
Y_x = size factor
Y_β = helix angle factor
$Y_{\delta\,rel\,T}$ = relative notch sensitivity factor
Z_E = material elasticity factor
Z_H = zone factor
Z_R = surface finish factor
Z_V = velocity factor
Z_X = size factor
Z_β = helix angle factor
Z_ε = contact ratio factor
α_{en} = pressure angle at the highest point of single tooth contact, in degrees
α_n = normal pressure angle at reference diameter, in degrees
α_t = transverse pressure angle at reference diameter, in degrees
α_{tw} = transverse pressure angle at pitch circle diameter, in degrees
$\alpha_{F\,en}$ = angle for application of load at the highest point of single tooth contact, in degrees
β = helix angle at reference diameter, in degrees
β_b = helix angle at base diameter, in degrees
γ = intermediary factor for the determination of f_{Sh}
ε_α = transverse contact ratio

$$= \frac{g_\alpha\cos\beta}{\pi\, m_n\cos\alpha_t}$$

$\varepsilon_{\alpha n}$ = virtual transverse contact ratio
ε_β = overlap ratio

$$= \frac{b\sin\beta}{\pi\, m_n}$$

ε_γ = total contact ratio
ρ_{ao} = tip radius of tool, in mm

ρ_c = relative radius of curvature at pitch point, in mm

$$= \frac{a \sin\alpha_{tw}\, u}{\cos\beta_b\,(1+u)^2}$$

ρ_F = tooth root fillet radius at the contact of the 30° tangent, in mm

σ_y = yield or 0,2 per cent proof stress, in N/mm^2

σ_B = ultimate tensile strength, in N/mm^2

σ_F = bending stress at tooth root, N/mm^2

$\sigma_{F\,lim}$ = endurance limit for bending stress in N/mm^2

σ_{FP} = allowable bending stress at the tooth root, in N/mm^2

σ_H = Hertzian contact stress at the pitch circle, in N/mm^2

$\sigma_{H\,lim}$ = endurance limit for Hertzian contact stress, in N/mm^2

σ_{HP} = allowable Hertzian contact stress, in N/mm^2

Subscript: $_1$ = pinion

$_2$ = wheel

$_0$ = tool.

3.2 Tooth form

3.2.1 The tooth profile in the transverse section is to be of involute shape, and the roots of the teeth are to be formed with smooth fillets of radii not less than 0,25 m_n.

3.2.2 All sharp edges left on the tips and ends of pinion and wheel teeth after hobbing and finishing are to be removed.

3.3 Tooth loading factors

3.3.1 For values of application factor, K_A, *see* Table 3.3.1.

Table 3.3.1 Values of K_A

Main and auxiliary gears	K_A
Main propulsion oil engine reduction gears:	
Hydraulic coupling or equivalent on input	1,10
High elastic coupling on input	1,30
Other coupling	1,50
Auxiliary gears:	
Electric and diesel engine drives with hydraulic coupling or equivalent on input	1,0
Diesel engine drives with high elastic coupling on input	1,20
Diesel engine drives with other couplings	1,40

3.3.2 Load sharing factor, K_γ. The value for K_γ is to be taken as 1,15 for multi-engine drives or split torque arrangements. Otherwise K_γ is to be taken as 1. Alternatively, where measured data exists, a derived value will be considered.

3.3.3 Dynamic factor, K_v:

For helical gears with $\varepsilon_\beta \geq 1$:

$$K_v = 1 + Q^2 v z_1\, 10^{-5} = K_{v\beta}$$

For helical gears with $\varepsilon_\beta < 1$:

$$K_v = K_{v\alpha} - \varepsilon_\beta\,(K_{v\alpha} - K_{v\beta})$$

For spur gears:

$$K_v = 1 + 1{,}8 Q^2 v z_1 10^{-5} = K_{v\alpha}$$

where $\frac{vz_1}{100} > 14$ for helical gears, and

where $\frac{vz_1}{100} > 10$ for spur gears, the value of K_v will be specially considered.

3.3.4 Longitudinal load distribution factors, $K_{H\beta}$ and $K_{F\beta}$:

$$K_{H\beta} = 1 + \frac{b\, F_{\beta y}\, C_\gamma}{2F_t K_A K_\gamma K_v}$$

Calculated values of $K_{H\beta} > 2$ are to be reduced by improved accuracy and helix correction as necessary:

where

$F_{\beta y}$ = $F_{\beta x} - y_\beta$ and

$F_{\beta x}$ = $1{,}33\, f_{Sh} + f_{ma}$

f_{ma} = $^2/_3\, F_\beta$ at the design stage, or

f_{ma} = $^1/_3\, F_\beta$ where helix correction has been applied

$$f_{Sh} = f_{Sho}\,\frac{F_t K_A K_\gamma K_v}{b}$$

where

f_{Sho} = $23\gamma 10^{-3}$ µm mm/N for gears without helix correction and without end relief, or

= $16\gamma 10^{-3}$ µm mm/N for gears without helix correction but with end relief

where

$$\gamma = \left(\frac{b}{d_1}\right)^2 \text{ for single helical and spur gears}$$

$$= 3\left(\frac{b}{2d_1}\right)^2 \text{ for double helical gears}$$

The following minimum values are applicable, these also being the values where helix correction has been applied:

f_{Sho} = 10×10^{-3} µm mm/N for helical gears, or

= 5×10^{-3} µm mm/N for spur gears

For through-hardened steels and surface hardened steels running on through-hardened steels:

$$y_\beta = \frac{320}{\sigma_{H\,lim}}\, F_{\beta x} \text{ when}$$

$$y_\beta \leq \frac{12800}{\sigma_{H\,lim}} \text{ µm, and}$$

For surface hardened steels, when

y_β = $0{,}15 F_{\beta x}$

y_β $\leq$ 6 µm

$K_{F\beta}$ = $K_{H\beta}^{\,n}$

where

$$n = \frac{\left(\frac{b}{h}\right)^2}{1 + \frac{b}{h} + \left(\frac{b}{h}\right)^2}$$

NOTES

1. $\frac{b}{h}$ is to be taken as the smaller of $\frac{b_1}{h_1}$ or $\frac{b_2}{h_2}$

2. For double helical gears is to be substituted for *b* in the equation for *n*.

3.3.5 Transverse load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$

$$K_{H\alpha} = K_{F\alpha} \geq 1{,}00$$

where

$\varepsilon\gamma \leq 2$

$$K_{H\alpha} = \frac{\varepsilon_\gamma}{2}\left\{0{,}9 + \frac{0{,}4C_\gamma (f_{pb} - y_\alpha)\, b}{F_t K_A K_\gamma K_v K_{H\beta}}\right\}$$

where

$\varepsilon\gamma > 2$

$$K_{H\alpha} = 0{,}9 + 0{,}4\sqrt{\frac{2(\varepsilon_\gamma - 1)}{\varepsilon_\gamma}}\left\{\frac{C_\gamma (f_{pb} - y_\alpha)\, b}{F_t K_A K_\gamma K_v K_{H\beta}}\right\}, \text{ but}$$

$$K_{H\alpha} \leq \frac{\varepsilon_\gamma}{\varepsilon_\alpha Z_\varepsilon^2} \quad \text{and}$$

$$K_{F\alpha} \leq \frac{\varepsilon_\gamma}{0{,}25\varepsilon_\gamma + 0{,}75}$$

When tip relief is applied, f_{pb} is to be half of the maximum specified value:

$$y_\alpha = \frac{160}{\sigma_{H\,lim}} f_{pb} \text{ for through-hardened steels, when}$$

$$y_\alpha \leq \frac{6400}{\sigma_{H\,lim}}\ \mu\text{m and}$$

$y_\alpha = 0{,}075 f_{pb}$ for surface hardened steels, when
$y_\alpha \leq 3\ \mu$m

When pinion and wheel are manufactured from different materials:

$$y_\alpha = \frac{y_{\alpha 1} + y_{\alpha 2}}{2}$$

3.3.6 Tooth mesh stiffness, C_γ:

$$C_\gamma = \frac{0{,}8}{q'} \cos\beta\,(0{,}75\varepsilon_\alpha + 0{,}25) \text{ N/mm } \mu\text{m}$$

where

$$q' = 0{,}04723 + \frac{0{,}1551}{z_{n1}} + \frac{0{,}25791}{z_{n2}} - 0{,}00635x_1 - \frac{0{,}11654x_1}{z_{n1}} - 0{,}00193x_2 - \frac{0{,}24188x_2}{z_{n2}} + 0{,}00529x_1^2 + 0{,}00182x_2^2$$

For internal gears $z_{n2} = \infty$

Other calculation methods for C_γ will be specially considered.

3.4 Tooth loading for surface stress

3.4.1 The Hertzian contact stress, σ_H, at the pitch circle is not to exceed the allowable Hertzian contact stress, σ_{HP}.

$$\sigma_H = Z_H Z_E Z_\varepsilon Z_\beta \frac{F_t (u+1)}{d_1 b u} K_A K_\gamma K_v K_{H\beta} K_{H\alpha} \quad \text{and}$$

$$\sigma_{HP} = \sqrt{\frac{\sigma_{H\,lim} Z_R Z_V Z_X}{S_{H\,min}}} \quad \text{for}$$

the pinion/wheel combination.

where

$$Z_H = \frac{2\cos\beta_b \cos\alpha_{tw}}{\cos^2\alpha_t \sin\alpha_{tw}}$$

Z_E = 189,8 for steel

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}(1 - \varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}} \quad \text{for } \varepsilon_\beta < 1 \text{ and}$$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} \quad \text{for } \varepsilon_\beta \geq 1$$

$$Z_\beta = \sqrt{\cos\beta}$$

$$Z_R = \left(\frac{1}{R_a}\right)^{0{,}11} \quad \text{but } Z_R \leq 1{,}14$$

where

R_a is the surface roughness value of the tooth flanks. When pinion and wheel tooth flanks differ, then the larger value of R_a is to be taken.

$$Z_v = 0{,}88 + 0{,}23\left(0{,}8 + \frac{32}{v}\right)^{-0{,}5}$$

For values of Z_x, *see* Table 3.3.2

For values of $\sigma_{H\,lim}$, *see* Table 3.3.3

For values of $S_{H\,min}$, *see* Table 3.3.4.

Table 3.3.2 Values of Z_x

Pinion heat treatment		Z_x
Carburized and induction-hardened	$m_n \leq 10$ $10 < m_n < 30$ $30 \leq m_n$	1,0 $1{,}05 - 0{,}005m_n$ 0,9
Nitrided	$m_n < 7{,}5$ $7{,}5 < m_n < 30$ $30 \leq m_n$	1,0 $1{,}08 - 0{,}011m_n$ 0,75
Through-hardened	All modules	1,0

Table 3.3.3 Values of endurance limit for Hertzian contact stress, $\sigma_{H\,lim}$

Heat treatment: Pinion	Heat treatment: Wheel	$\sigma_{H\,lim}$ N/mm^2
Through-hardened	Through-hardened	$0{,}46\sigma_{B2} + 255$
Surface-hardened	Through-hardened	$0{,}42\sigma_{B2} + 415$
Carburized, nitrided or induction-hardened	Soft bath nitrided (Tufftrided)	1000
Carburized, nitrided or induction-hardened	Induction-hardened	$0{,}88\ Hv_2 + 675$
Carburized or nitrided	Nitrided	1300
Carburized	Carburized	1500

Table 3.3.4 Factors of safety

	$S_{H\,min}$	$S_{F\,min}$
Main propulsion gears	1,25	1,50
Main propulsion gears for multiple screw	1,20	1,45
Auxiliary gears	1,15	1,40

3.5 Tooth loading for bending stress

3.5.1 The bending stress at the tooth root, σ_F is not to exceed the allowable tooth root bending stress σ_{FP}

$$\sigma_F = \frac{F_t}{bm_n} Y_F Y_S Y_\beta K_A K_\gamma K_v K_{F\beta} K_{F\alpha} \quad \text{N/mm}^2$$

$$\sigma_{FP} = \frac{\sigma_{F\,lim} Y_{ST} Y_{\delta\,rel\,T} Y_{R\,rel\,T} Y_x}{S_{F\,min} Y_D} \quad \text{N/mm}^2$$

For values of $S_{F\,min}$, *see* Table 3.3.4

For values of $\sigma_{F\,lim}$, *see* Table 3.3.5.

Stress correction factor $Y_{ST} = 2$.

3.5.2 Tooth form factor, Y_F:

$$Y_F = \frac{6\dfrac{h_F}{m_n}\cos\alpha_{F\,en}}{\left(\dfrac{S_{Fn}}{m_n}\right)^2 \cos\alpha_n}$$

where

h_F, $\alpha_{F\,en}$ and S_{Fn} are shown in Fig. 3.3.1.

$$\frac{S_{Fn}}{m_n} = z_n \sin\left(\frac{\pi}{3} - \nu\right) + \sqrt{3}\left(\frac{G}{\cos\nu} - \frac{\rho_{ao}}{m_n}\right)$$

where

$$\nu = \frac{2G}{z_n}\tan\nu - H$$

Table 3.3.5 Values of endurance limit for bending stress, $\sigma_{F\,lim}$

Heat treatment	$\sigma_{F\,lim}$ N/mm^2
Through-hardened carbon steel	$0{,}09\sigma_B + 150$
Through-hardened alloy steel	$0{,}1\sigma_B + 185$
Soft bath nitrided (Tufftrided)	330
Induction hardened	0,35 Hv + 125
Gas nitrided	390
Carburized A	450
Carburized B	410

NOTES
1. A is applicable for Cr Ni Mo carburizing steels.
2. B is applicable for other carburizing steels.

$$G = \frac{\rho_{ao}}{m_n} - \frac{h_{ao}}{m_n} + x$$

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{3}$$

$$E = \frac{\pi}{4} m_n - h_{ao}\tan\alpha_n + \frac{S_{pr}}{\cos\alpha_n} - (1 - \sin\alpha_n)\frac{\rho_{ao}}{\cos\alpha_n}$$

E, h_{ao}, α_n, S_{pr} and ρ_{ao} are shown in Fig. 3.3.2

$$\frac{\rho_F}{m_n} = \frac{\rho_{ao}}{m_n} + \frac{2G^2}{\cos\nu\,(z_n\cos^2\nu - 2G)}$$

$$d_{en} = \frac{2z}{|z|}\left\{\left[\sqrt{\left(\frac{d_{an}}{2}\right)^2 - \left(\frac{d_{bn}}{2}\right)^2} - \frac{\pi d\cos\beta\cos\alpha_n}{|z|}(\varepsilon_{\alpha n} - 1)\right]^2 + \left(\frac{d_{bn}}{2}\right)^2\right\}^{1/2}$$

where

$$d_{an} = d_n + d_a - d$$

$$d_n = \frac{d}{\cos^2\beta_b}$$

$$d_{bn} = d_n\cos\alpha_n$$

$$\varepsilon_{\alpha n} = \frac{\varepsilon_\alpha}{\cos^2\beta_b}$$

$$\gamma_e = \frac{\dfrac{\pi}{2} + 2x\tan\alpha_n}{z_n} + \text{inv.}\,\alpha_n - \text{inv.}\,\alpha_{en}$$

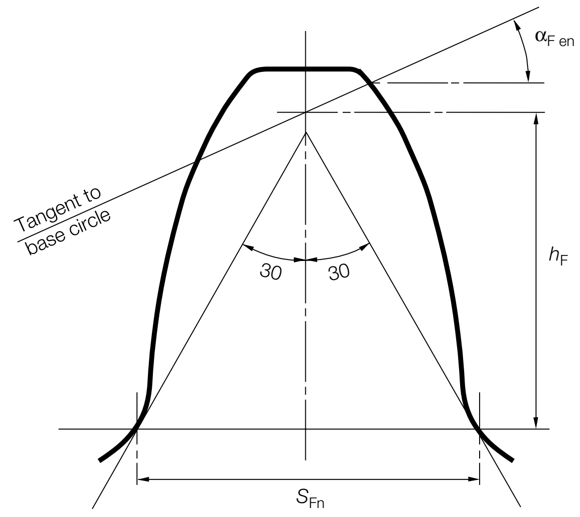
where

$$\alpha_{en} = \arccos\frac{d_{bn}}{d_{en}}$$

$$\frac{h_F}{m_n} = \frac{1}{2}\left[(\cos\gamma_e - \sin\gamma_e\tan\alpha_{F\,en})\frac{d_{en}}{m_n} - z_n\cos\left(\frac{\pi}{3} - \nu\right) - \frac{G}{\cos\nu} + \frac{\rho_{ao}}{m_n}\right]$$

where

$$\alpha_{F\,en} = \alpha_{en} - \gamma_e$$



NOTE
For helical gears the normal section is taken with the virtual number of teeth

Fig. 3.3.1 Normal tooth section

3.5.3 For internal tooth forms, the form factor is calculated, as an approximation, for a substitute gear rack with the form of the basic rack in the normal section, but having the same tooth depth as the internal gear.

$$\frac{S_{Fn2}}{m_n} = 2\left[\frac{\pi}{4} + \tan\alpha\left(\frac{h_{ao2} - \rho_{ao2}}{m_n}\right) + \left(\frac{\rho_{ao2} - S_{pr}}{m_n \cos\alpha_n}\right) - \frac{\rho_{ao2}}{m_n}\cos\frac{\pi}{6}\right], \text{ and}$$

$$\frac{h_{F2}}{m_n} = \frac{d_{en2} - d_{fn2}}{2m_n} - \left[\frac{\pi}{4} + \left(\frac{h_{ao2}}{m_n} - \frac{d_{en2} - d_{fn2}}{2m_n}\right)\tan\alpha_n\right]\tan\alpha_n - \frac{\rho_{ao2}}{m_n}\left(1 - \sin\frac{\pi}{6}\right)$$

where
$\alpha_{F\,en}$ is taken as being equal to an

$$\rho_{F2} = \frac{\rho_{ao2}}{2}$$

d_{en2} is calculated as d_{en} for external gears, and
$d_{fn} = d - d_f - d_n$

3.5.4 Stress concentration factor, Y_S

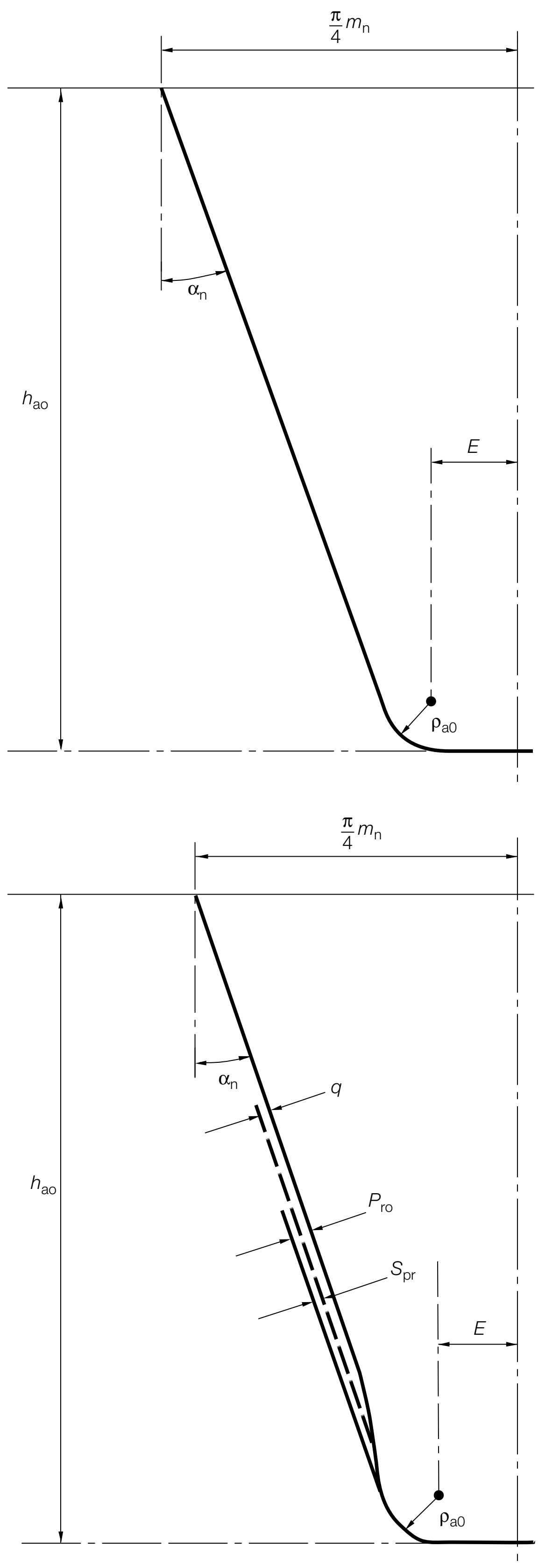
$$Y_s = (1{,}2 + 0{,}13L)\, q_s^{\left(\frac{1}{1{,}21 + 2{,}3/L}\right)}$$

where

$$L = \frac{S_{Fn}}{h_F}$$

$$q_s = \frac{S_{Fn}}{\rho}$$

when



NOTES
1. Dimensions shown on rack profile of tooth
2. $S_{pr} = P_{ro} - q$

Fig. 3.3.2 External tooth forms

$q_s < 1$, the value of Y_s is to be specially considered.

The formula for Y_s is applicable to external gears with $\alpha_n = 20°$ but may be used as an approximation for other pressure angles and internal gears.

3.5.5 Helix angle factor, Y_β

$$Y_\beta = 1 - \left(\varepsilon_\beta \frac{\beta}{120}\right), \text{ if } \varepsilon_\beta > 1 \text{ let } \varepsilon_\beta = 1$$

but

$$Y_b \geq 1 - 0{,}25\varepsilon_\beta \geq 0{,}75$$

3.5.6 Relative notch sensitivity factor, $Y_{\delta\ rel\ T}$

$Y_{\delta\ rel\ T} = 1 + 0{,}036\ (q_s - 2{,}5)\left(1 - \frac{\sigma_y}{1200}\right)$ for through-hardened steels

$Y_{\delta\ rel\ T} = 1 + 0{,}008\ (q_s - 2{,}5)$ for carburized and induction-hardened steels, and

$Y_{\delta\ rel\ T} = 1 + 0{,}04\ (q_s - 2{,}5)$ for nitrided steels

3.5.7 Relative surface finish factor, $Y_{R\ rel\ T}$

$Y_{R\ rel\ T} = 1{,}674 - 0{,}529\ (6R_a + 1)^{0{,}1}$ for through-hardened, carburized and induction hardened steels, and

$Y_{R\ rel\ T} = 4{,}299 - 3{,}259\ (6R_a + 1)^{0{,}005}$ for nitrided steels

3.5.8 Size factor, Y_x

$Y_x = 1{,}0$, when $m_n \leq 5$
$Y_x = 1{,}03 - 0{,}006 m_n$ for through hardened steels
$Y_x = 0{,}85$, when $m_n \geq 30$
$Y_x = 1{,}05 - 0{,}01\ m_n$ for surface-hardened steels
$Y_x = 0{,}80$, when $m_n \geq 25$

3.5.9 Design factor, Y_D

$Y_D = 0{,}83$ for gears treated with a controlled shot peening process
$Y_D = 1{,}5$ for idler gears
$Y_D = 1{,}25$ for shrunk on gears, or

$$Y_D = 1 + \frac{0{,}2 d_s^2\ d P_r\ b}{F_t\ \sigma_{F\ lim}\ (d_f^{\ 2} - d_s^2)}, \text{ otherwise}$$

$Y_D = 1{,}0$.

3.6 Factors of safety

3.6.1 Factors of safety are shown in Table 3.3.4.

3.7 Design of enclosed gear shafting

3.7.1 The following symbols apply:

P in kW and R in rpm, *see* Ch 1,3.3.1

L = span between shaft bearing centres, in mm
α_n = normal pressure angle at the gear reference diameter, in degrees
β = helix angle at the gear reference diameter, in degrees
d_w = pitch circle diameter of the gear teeth, in mm
σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

NOTE
Numerical value used for σ_u is not to exceed 800 N/mm^2 for gear and thrust shafts and 1100 N/mm^2 for quill shafts.

3.7.2 This sub-Section is applicable to the main and ancillary transmission shafting, enclosed within the gearcase.

3.7.3 The diameter of the enclosed gear shafting adjacent to the pinion or wheel is to be not less than the greater of d_b or d_t, where:
where

$$d_b = 365\left(\frac{P\,L}{R\,d_w\,S_b}\right)^{1/3}\left[1 + \left(\frac{\tan\alpha_n}{\cos\beta} + \frac{\tan\beta\ d_w}{L}\right)^2\right]^{1/6}$$

$$d_t = 365\left(\frac{P}{R\,S_s}\right)^{1/6}$$

where

$$s_b = 45 + 0{,}24(\sigma_u - 400)$$

and

$$s_s = 42 + 0{,}09(\sigma_u - 400)$$

3.7.4 For the purposes of the above, it is assumed that the pinion or wheel is mounted symmetrically spaced between bearings.

3.7.5 Outside a length equal to the required diameter at the pinion or wheel, the diameter may be reduced, if applicable, to that required for d_t.

3.7.6 For bevel gear shafts, where a bearing is located adjacent to the gear section, the diameter of the shaft is to be not less than d_t. Where a bearing is not located adjacent to the gear the diameter of the shaft will be specially considered.

3.7.7 The diameter of quill shaft (not axially constrained and subject only to external torsional loading) is to be not less than given by the following formula:
Diameter of quill shaft:

$$d_q = 101\sqrt[3]{\frac{P\,400}{R\,\sigma_u}}\ \text{mm}$$

3.7.8 Where a shaft, located within the gearcase, is subject to the main propulsion thrust, the diameter at the collars of the shaft transmitting torque, or in way of the axial bearing where a roller bearing is used as a thrust bearing, is to be not less than $1{,}1 d_t$. For thrust bearings located outside the gearcase, *see* Chapter 4.

3.8 External shafting and components

3.8.1 For shafting external to the gearbox and other components ancillaries, *see* Pt 5, Ch 4.

■ *Section 4* **Construction**

4.1 Gear wheels and pinions

4.1.1 Where castings are used for wheel centres, any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

4.1.2 Where bolts are used to secure side plates to rim and hub, the bolts are to be a tight fit in the holes and the nuts are to be suitably locked by means other than welding.

4.1.3 Where welding is employed in the construction of wheels, the welding procedure is to be approved by the Surveyor before work is commenced. For this purpose, welding procedure approval tests are to be carried out with satisfactory results. Such tests are to be representative of the joint configuration and materials. Wheels are to be stress relieved after welding. All welds are to have a satisfactory surface finish and contour. Magnetic particle or liquid penetrant examination of all important welded joints is to be carried out to the satisfaction of the Surveyor.

4.1.4 In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

4.2 Accuracy of gear cutting and alignment

4.2.1 The machining accuracy (Q grade) of pinions and wheels is to be demonstrated to the satisfaction of the Surveyor. For this purpose, records of measurements should be available for review by the Surveyor on request.

4.2.2 Where allowance has been given for end relief or helix correction, the normal shop meshing tests are to be supplemented by tooth alignment traces or other approved means to demonstrate the effectiveness of such modifications.

4.3 Gearcases

4.3.1 Gearcases and their supports are to be designed sufficiently stiff such that misalignment at the mesh due to movements of the external foundations and the thermal effects under all conditions of service do not disturb the overall tooth contact.

4.3.2 For gearcases fabricated by fusion welding the carbon content of steels should generally not exceed 0,23 per cent. Steels with higher carbon content may be approved subject to satisfactory results from weld procedure tests.

4.3.3 The welding is to be carried out in positions free from draughts and is to be downhand (flat) wherever practicable. Welding consumables are to be suitable for the materials being joined.

4.3.4 Gearcases are to be stress relief heat treated on completion of all welding.

4.3.5 Inspection openings are to be provided at the peripheries of gearcases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gearcases is such that sections of the structure cannot readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gearcases to permit examination of the structure of the wheels. Their attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

4.3.6 Gear cases manufactured from material other than steel will be considered upon full details being submitted.

■ *Section 5* **Tests**

5.1 Balance of gear pinions and wheels

5.1.1 All rotating elements, e.g. pinion and wheel shaft assemblies and coupling parts, are to be appropriately balanced.

5.1.2 The permissible residual unbalance, *U*, is defined as follows:

$$U = \frac{60\,m}{N} \times 10^3 \text{ g mm for } N \leq 3000$$

$$U = \frac{24\,m}{N} \times 10^3 \text{ g mm for } N > 3000$$

where

m = mass of rotating element, kg

N = maximum service rev/min of the rotating element.

5.1.3 Where the size or geometry of a rotating element precludes measurement of the residual unbalance, a full speed running test of the assembled gear unit at the manufacturer's works will normally be required to demonstrate satisfactory operation.

5.2 Meshing tests

5.2.1 Initially, meshing gears are to be carefully matched on the basis of the accuracy measurements taken. The alignment is to be demonstrated in the workshop by meshing in the gearbox without oil clearance in the bearings. Meshing is to be carried out with the gears locating in their light load positions and a load sufficient to overcome pinion weight and axial movement is to be imposed.

5.2.2 The gears are to be suitably coated to demonstrate the contact marking. The marking is to reflect the accuracy grade specified and end relief of helix correction, where these have been applied.

5.2.3 For gears without helix correction, the marking is to be not less than shown in Table 3.5.1.

5.2.4 For gears with end relief of helix correction, the marking is to correspond to the designed no load contact pattern.

Table 3.5.1 No load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5	40% h_w for 50% *b* and 20% h_w for a further 40% *b*
Q ≥ 6	40% h_w for 35% *b* and 20% h_w for a further 35% *b*

NOTES
1. Where *b* is face width and h_w is working tooth depth.
2. For spur gears, the values of h_w should be increased by a further 10%.

5.2.5 A permanent record is to be made of the meshing contact for purpose of checking the alignment when installed on board ship.

5.2.6 The full load tooth contact marking is to be not less than shown in Table 3.5.2.

Table 3.5.2 Full load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5	70% h_w for 60% *b* and 50% h_w for a further 30% *b*
Q ≥ 6	60% h_w for 45% *b*and 40% h_w for a further 35% *b*

NOTES
1. Where *b* is face width and h_w is working tooth depth.
2. For spur gears, the values of h_w should be increased by a further 10%.

5.3 Alignment

5.3.1 Reduction gears with sleeve bearings, for main and auxiliary purposes, are to be provided with means for checking the internal alignment of the various elements in the gearcases.

5.3.2 In the case of separately mounted reduction gearing for main propulsion, means are to be provided by the gear manufacturer to enable the Surveyor to verify that no distortion of the gearcase has taken place, when chocked and secured to its seating on board ship.

■ *Cross-reference*

For lubricating oil systems, *see* Chapter 12.

■ *Scope*

The requirements of this Chapter relate, in particular, to formulae for determining the diameters of shafting for main propulsion installations, but requirements for couplings, coupling bolts, keys, keyways, sternbushes and other associated components are also included. The diameters may require to be modified as a result of alignment considerations and vibration characteristics, *see* Chapter 6, or the inclusion of stress raisers, other than those contained in this Chapter.

■ *Section 1*
Plans and particulars

1.1 Shafting plans

1.1.1 The following plans, together with the necessary particulars of the machinery, including the maximum power and revolutions per minute, are to be submitted for consideration before the work is commenced:

Thrust shaft
Intermediate shafting
Tube shaft, where applicable
Screwshaft
Screwshaft oil gland
Sternbush.

1.1.2 The specified minimum tensile strength of each shaft is to be stated.

1.1.3 In addition, a shafting arrangement plan indicating the relative position of the main engines, flywheel, flexible coupling, gearing, thrust block, line shafting and bearings, sterntube, 'A' bracket and propeller, as applicable, is to be submitted for information.

■ *Section 2*
Materials

2.1 Materials for shafts

2.1.1 The specified minimum tensile strength of forgings for shafts is to be selected within the following general limits:

(a) Carbon and carbon-manganese steel 400 to 760 N/mm^2
(b) Alloy steel not exceeding 800 N/mm^2

2.1.2 Where materials with greater specific or actual tensile strengths than the limitations given above are used, reduced shaft dimensions or higher permissible vibration stresses are not acceptable when derived from the formulae used in Section 3.2, 3.4, 3.5 and Ch 6,2.5.

2.1.3 Where it is proposed to use alloy steel, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

■ *Section 3*
Design

3.1 Fatigue strength analysis

3.1.1 As an alternative to the following requirements, a fatigue strength analysis of components can be submitted indicating a factor of safety of 1.5 at the design loads, based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

3.2 Intermediate shafts

3.2.1 The diameter, *d*, of the intermediate shaft is to be not less than determined by the following formula:

$$d = F\,k\,\sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)}\ \text{mm}$$

k = 1,0 for shafts with integral coupling flanges complying with 3.7 or with shrink fit couplings

k = 1,10 for shafts with keyways in tapered or cylindrical connections where the fillet radii in the transverse section of the bottom of the keyway are to be not less than 0,0125*d*

F = 89 for electric propulsion installations

F = 94 for diesel engine installations

P and *R* are defined in Ch 1,3.3 (losses in gearboxes and bearings are to be disregarded)

σ_u = specified minimum tensile strength of the material, in N/mm^2

After a length of 0,2*d* from the end of a keyway the diameter of the shaft may be gradually reduced to that determined with *k*=1,0.

3.2.2 For shafts with design features other than stated as above, the value of *k* will be specially considered.

3.2.3 Carbon-manganese steel intermediate shafts having flanges attached by fusion welding may be accepted provided that the following conditions are complied with:

(a) The materials are of a weldable quality with a carbon content generally not exceeding 0,23 per cent and the carbon equivalent not exceeding 0,4 per cent.
(b) The weld is of a full penetration type.
(c) Welding is to be in accordance with an LR approved procedure.
(d) The welding is carried out by qualified welders.
(e) The shaft fillet radius and flange are machined all over. Particular attention is to be paid to the smooth blending of the fillet radius.
(f) The welds are subsequently examined by magnetic crack detection methods all to the Surveyor's satisfaction.
(g) The shaft is to be post-weld heat treated at a temperature of 650°C with a holding time of one hour per 25 mm of weld thickness and thereafter allowing the structure to cool slowly in the furnace.
(h) The whole of the work is carried out to the Surveyor's satisfaction.

For a typical example of this type of coupling, *see* Fig. 4.3.1. Alternative methods of attaching the coupling flanges to intermediate shafts will be specially considered.

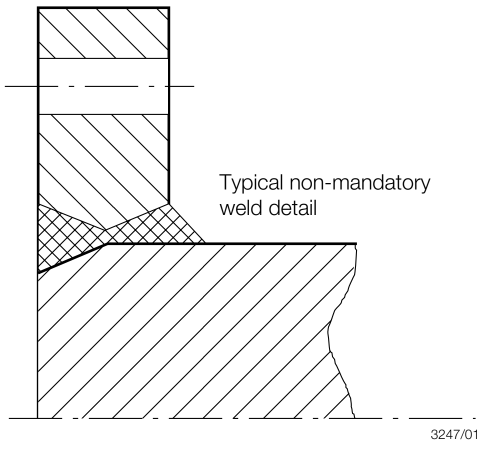


Fig. 4.3.1
Typical example of coupling welded to intermediate shaft

3.3 Thrust shafts

3.3.1 The diameter collars of the thrust shaft transmitting torque, or in way of the axial bearing where a roller bearing is used as a thrust bearing, is to be not less than that required for the intermediate shaft in accordance with 3.2.1 with a *k* value of 1,10. Outside a length equal to the thrust shaft diameter from the collars, the diameter may be tapered down to that required for the intermediate shaft with a *k* value of 1,0. For the purpose of the foregoing calculations, σ_u is to be taken as the minimum tensile strength of the thrust shaft material, in N/mm^2. The fillet radius at the base of both sides of the thrust collar is to be not less than 0,08 of the diameter of the shaft at the collar.

3.4 Screw shafts and tube shafts

3.4.1 For screw shafts and tube shafts, (i.e. the shaft which passes through the stern tube, but does not carry the propeller), made from carbon manganese steel and protected by approved oil sealing glands, the requirements of 3.4.2 to 3.4.5 are applicable.

3.4.2 The diameter, d_p of the protected screw shaft immediately forward of the forward face of the propeller boss or, if applicable, the forward face of the screw shaft flange, is to be not less than determined by the following formula:

$$d = 94k \sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \text{ mm}$$

where

k = 1,22 for a shaft carrying a keyless propeller fitted on a taper, or where the propeller is attached to an integral flange, and where the shaft is oil lubricated and provided with an approved type of oil sealing gland
= 1,26 for a shaft carrying a keyed propeller and where the shaft is oil lubricated and provided with an approved type of oil sealing gland

P and *R* are defined in Ch 1,3.3 (losses in gearboxes and bearings are to be disregarded)

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2 but is not to be taken as greater than 600 N/mm^2.

3.4.3 The diameter, d_p of the screw shaft determined in accordance with the formula in 3.4.2 is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or 2,5d_p whichever is the greater.

3.4.4 The diameter of the portion of the screw shaft and tube shaft, forward of the length required by 3.4.2 to the forward end of the forward stern tube seal, is to be determined in accordance with the formula in 3.4.2 with a *k* value of 1,15. The change of diameter from that determined with *k* = 1,22 or 1,26 to that determined with *k* = 1,15 should be gradual, *see* 3.7.

3.4.5 Screw shafts which run in stern tubes and tube shafts may have the diameter forward of the forward stern tube seal gradually reduced to the diameter of the intermediate shaft. Abrupt changes in shaft section at the screw shaft/tube shaft to intermediate shaft couplings are to be avoided, *see* 3.7.

3.4.6 The diameter of unprotected screw shafts and tube shafts of materials having properties as shown in Table 4.3.1 is to be not less than:

$$d_{up} = 128\,A \sqrt[3]{\frac{P}{R}}$$

where '*A*' is taken from Table 4.3.1.

Table 4.3.1 Provisional 'A' value for use in unprotected screw shaft formula

Material	'A' Value
Stainless steel type 316 (austenitic)	0,71
Stainless steel type 431 (martensitic)	0,69
Manganese bronze	0,8
Nickel/aluminium bronze	0,65
Nickel copper alloy – monel 400	0,65
Nickel copper alloy – monel K 500	0,55
Duplex steels	0,49

3.4.7 For shafts of non-corrosion-resistant materials which are exposed to outboard water, the diameter of the shaft is to be determined in accordance with the formula in 3.4.2 with a *k* value of 1,26 and σ_u taken as 400 N/mm^2.

3.4.8 The diameter of the unprotected screw shaft forward of the stern seal need not be greater than the diameter as required by 3.4.5.

3.5 Hollow shafts

3.5.1 Where the thrust, intermediate, tube shafts and screw shafts have central holes, having a diameter greater than 0,4 times the outside diameter, the equivalent diameter d_e of a solid shaft is not to be less than the Rule size, *d*, (of a solid shaft), where d_e is given by:

$$d_e = d_o \sqrt[3]{1 - \left(\frac{d_i}{d_o}\right)^4}$$

where

d_o = proposed outside diameter, in mm

d_i = diameter of central hole, in mm.

3.5.2 Where the diameter of the central hole does not exceed 0,4 times the outside diameter, the diameter is to be calculated in accordance with the appropriate requirements for a solid shaft.

3.6 Cardan shafts

3.6.1 Cardan shafts, used in installations having more than one propulsion shaftline, are to be of an approved design, suitable for the designed operating conditions including short term high power operation. Consideration will be given to accepting the use of approved cardan shafts in single propulsion unit applications if a complete spare coupling is to be provided on board.

3.6.2 Cardan shaft ends are to be contained within substantial tubular guards that also permit ready access for inspection and maintenance.

3.7 Couplings and transitions of diameters

3.7.1 The minimum thicknesses of the coupling flanges are to be equal to the diameters of the coupling bolts at the face of the couplings as required by 3.8, and for this purpose the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. For intermediate shafts, thrust shafts and the inboard end of the screwshaft, the thickness of the coupling flange is in no case to be less than 0,20 of the diameter of the intermediate shaft as required by 3.2.

3.7.2 The fillet radius at the base of the coupling flange is to be not less than 0,08 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and are not to be recessed in way of nuts and bolt heads.

3.7.3 Where the propeller is attached by means of a flange, the thickness of the flange is to be not less than 0,25 of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of the coupling flange is to be not less than 0,125 of the diameter of the shaft at the coupling.

3.7.4 All couplings which are attached to shafts are to be of approved dimensions.

3.7.5 Where couplings are separate from the shafts, provision is to be made to resist the astern pull.

3.7.6 Where a coupling is shrunk onto the parallel portion of a shaft or is mounted on a slight taper, e.g. by means of the oil pressure injection method, full particulars of the coupling including the interference fit are to be submitted for special consideration.

3.7.7 Transitions of diameters are to be designed with either a smooth taper or a blending radius. In general a blending radius equal to the change in diameter is recommended.

3.8 Coupling bolts

3.8.1 Close tolerance fitted bolts transmitting shear are to have a diameter, d_b, at the flange joining faces of the couplings not less than:

$$d_b = \sqrt{\frac{212\ 10^6 P}{n\ D\ \sigma_u\ R}} \text{ mm}$$

where

n = number of bolts in the coupling

D = pitch circle diameter of bolts, in mm

σ_u = specified minimum tensile strength of bolts, in N/mm^2

P and *R* are as defined in Ch 1, 3.3.

3.8.2 The minimum diameter of tap bolts or of bolts in clearance holes at the joining faces of coupling flanges, pretensioned to 70 per cent of the bolt material yield strength value, is not to be less than:

$$d_R = 1.267 \sqrt{\left[\frac{120\ 10^6 F\, P\, (1 + C)}{R\, D} + Q\right] \frac{1}{n\, \sigma_y}}$$

where

d_R is taken as the lesser of:

(a) Mean of effective (pitch) and minor diameters of the threads.

(b) Bolt shank diameter away from threads. (Not for waisted bolts which will be specially considered.)

P and *R* are defined in Ch 1,3.3.

F = 2,5 where the flange connection is not accessible from within the ship or vessel
  = 2,0 where the flange connection is accessible from within the ship or vessel

C = ratio of vibratory/mean torque values at the rotational speed being considered

D = pitch circle diameter of bolt holes, in mm

Q = external load on in N (+ve tensile load tending to separate flange, –ve)

n = number of tap or clearance bolts

σ_y = bolt material yield stress in N/mm^2.

3.8.3 Consideration will be given to those arrangements where the bolts are pre-tensioned to loads other than 70 per cent of the material yield strength.

3.9 Keys and keyways for propeller connections

3.9.1 Round ended or sled-runner ended keys are to be used, and the keyways in the propeller boss and cone of the screwshaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screwshaft at the top of the cone. The sharp edges at the top of the keyways are to be removed.

3.9.2 For sled-runner ended keys at least one screwed pin is to be provided for securing the key in the keyway, and the forward pin is to be placed at least one-third of the length of the key from the end. The depth of the tapped holes for the screwed pins is not to exceed the pin diameter, and the edges of the holes are to be slightly bevelled.

3.9.3 The distance between the top of the cone and the forward end of the keyway is to be not less than 0,2 of the diameter of the screwshaft at the top of the cone.

3.9.4 The effective sectional area of the key in shear, is to be not less than:

$$A = \frac{155\, d^3}{\sigma_u\, d_1} \text{ mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with 3.2, based on material having a specified minimum tensile strength of 400 N/mm^2 and k = 1

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2.

3.9.5 The effective area in crushing of key, shaft or boss is to be not less than:

$$A = \frac{24 d^3}{\sigma_y\, d_1} \text{ mm}^2$$

where

σ_y = yield strength of key, shaft or boss material as appropriate, N/mm^2.

3.10 Keys and keyways for inboard shaft connections

3.10.1 Round ended keys are to be used and the keyways are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the shaft at the coupling. The sharp edges at the top of the keyways are to be removed.

3.10.2 The effective area of the key in shear, *A*, is to be not less than:

$$A = \frac{126 d^3}{\sigma_u\, d_1} \text{ mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with 3.2, based on material having a specified minimum tensile strength of 400 N/mm^2 and k = 1

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2.

3.10.3 For the effective area in crushing of key, shaft or boss *see* 3.9.5. Alternatively, consideration will be given to keys conforming to the design requirements of a recognised National Standard.

3.11 Interference fit assemblies

3.11.1 The interference fit assembly is to have a capacity to transmit a torque of $S.T_{max}$ without slippage.

NOTE

For guidance purposes only,

$$T_{max} = T_{mean}\,(1 + C)$$

where

C is to be taken from Table 4.3.2

S = 2,0 for assemblies accessible from within the vessel
  = 2,5 for assemblies not accessible from within the vessel.

3.11.2 The effect of any axial load acting on the assembly is to be considered.

3.11.3 The resulting equivalent von Mises stress in the assembly is not to be greater than the yield strength of the component material.

3.11.4 Reference marks are to be provided on the adjacent surfaces of parts secured by shrinkage alone.

Table 4.3.2 'C' values for guidance purposes

Coupling location	*C*
High speed shafting – I.C. engine driven	0,3
High speed shafting Electric motor driven	0,1
Low speed shafting – main or PTO stage gearing	0,1

3.12 Sternbushes and sterntube arrangement

3.12.1 Where the sterntube or sternbushes are to be installed using a resin, of an approved type, the following requirements are to be met:

(a) Pouring and venting holes are to be provided at opposite ends with the vent hole at the highest point.
(b) The minimum radial gap occupied by the resin is to be not less than 6 mm at any one point with a nominal resinthickness of 12 mm.
(c) In the case of oil lubricated sterntube bearings, the arrangement of the oil grooves is to be such as to promote a positive circulation of oil in the bearing.

3.12.2 The length of the bearing in the sternbush next to and supporting the propeller is to be as follows:

(a) For water lubricated bearings which are lined with rubber composition or staves of approved plastics material, the length is to be not less than four times the diameter required for the screwshaft under the liner.
(b) For water lubricated bearings lined with two or more circumferentially spaced sectors or an approved plastics material, in which it can be shown that the sectors operate on hydrodynamic principles, the length of the bearing is to be such that the nominal bearing pressure will not exceed 0,55 N/mm^2 (5,6 kgf/mm^2). The length of the bearing is to be not less than twice its diameter.
(c) For bearings which are white-metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be approximately twice the diameter required for the screwshaft and is to be such that the nominal bearing pressure will not exceed 0,8 N/mm^2 (8,1 kgf/cm^2). The length of the bearing is to be not less than 1,5 times its diameter.
(d) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil sealing gland, the length of the bearing is, in general, to be not less than four times the diameter required for the screwshaft.
(e) For bearings which are grease lubricated, the length of the bearing is to be not less than four times the diameter required for the screwshaft.
(f) Oil lubricated non metallic bearings are to be manufactured from an approved material. The length of the bearing is to be such that the maximum approved bearing pressure is not exceeded for any limiting length to diameter ratio.

3.12.3 Sternbushes are to adequately secured in housings.

3.12.4 Forced water lubrication is to be provided for all bearings lined with rubber or plastics. The supply of water may come from a circulating pump or other pressure source. Flow indicators with an alarm in the wheelhouse are to be provided for the water service to plastics and rubber bearings. The water grooves in the bearings are to be of ample section and of a shape which will be little affected by weardown, particularly for bearings for the plastics type.

3.12.5 For forced water lubricating systems an alarm is to be provided in the wheelhouse for pump failure. *See* Pt 6, Ch 1.

3.12.6 The shut-off valve or cock controlling the supply of water is to be fitted direct to the after peak bulkhead, or to the sterntube where the water supply enters the sterntube forward of the bulkhead.

3.12.7 Where a tank supplying lubricating oil to the sternbush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm device in the engine room.

3.12.8 Where sternbush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the sterntube or by other approved means.

3.12.9 Oil sealing glands must be capable of accommodating the effects of differential expansion between hull and line of shafting for all water temperatures in the proposed area of operation. This requirement applies particularly to those glands which span the gap and maintain oil tightness between the stern tube and the propeller boss.

3.12.10 Water sealing glands must be capable of accommodating the effects of differential expansion between hull and line of shafting for all water temperatures in the proposed area of operation. Two independent sealing glands are to be provided or alternatively one sealing gland capable of being replaced when the ship is afloat.

3.13 Vibration and alignment

3.13.1 For the requirements for shaft vibration and alignment, *see* Chapter 6.

Section 1
Plans and particulars

1.1 Details to be submitted

1.1.1 A plan, in triplicate, of the propeller is to be submitted for approval, together with the following particulars using the symbols shown:

(a) Maximum blade thickness of the expanded cylindrical section considered, T, in mm.
(b) Maximum shaft power (*see* Ch 1,3.3), P, in kW.
(c) Estimated ship speed at design loaded draught in the free running condition at maximum shaft power and corresponding revolutions per minute (*see* (b) and (d)).
(d) Revolutions per minute of the propeller at maximum power, R.
(e) Propeller diameter, D, in metres.
(f) Pitch at 25 per cent radius (for solid propellers only), $P_{0,25}$, in metres.
(g) Pitch at 35 per cent radius (for controllable pitch propellers only), $P_{0,35}$, in metres.
(h) Pitch at 60 per cent radius $P_{0,6}$, in metres
(j) Pitch at 70 per cent radius $P_{0,7}$, in metres
(k) Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid propellers only), $L_{0,25}$, in mm.
(l) Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only) $L_{0,35}$, in mm.
(m) Length of blade section of the expanded cylindrical section at 60 per cent radius, $L_{0,6}$, in mm.
(n) Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative), A, in mm.
(o) Number of blades, N.
(p) Developed area ratio, B.
(q) Material: type and specified minimum tensile strength.
(r) θ_s, skew angle, in degrees, (*see* Fig. 5.1.1).
(s) Connection of propeller to shaft – details of fit, push-up, securing, etc.

1.1.2 For propellers having a skew angle equal to or greater than 50°, in addition to the particulars detailed in 1.1.1 details are to be submitted of:

(a) Full blade section details at each radial station defined for manufacture.
(b) A detailed blade stress computation supported by the following hydrodynamic data for the ahead mean wake condition and when absorbing full power:
  (i) Radial distribution of lift and drag coefficients, section inflow velocities and hydrodynamic pitch angles.
  (ii) Section pressure distributions calculated by either an advised inviscid or viscous procedure.

1.1.3 For blades of fixed pitch propellers with skew angle of 30° or greater, the stresses in the propeller blade during astern operation are not to exceed 80 per cent of the propeller blade material proof stress. Consideration is to be given to failure conditions and a factor of safety of 1,5 is to be attained using an acceptable fatigue failure criteria. Documentary evidence confirming that these criteria are satisfied is to be submitted.

1.1.4 The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centreline and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade sections, *see* Fig. 5.1.1.

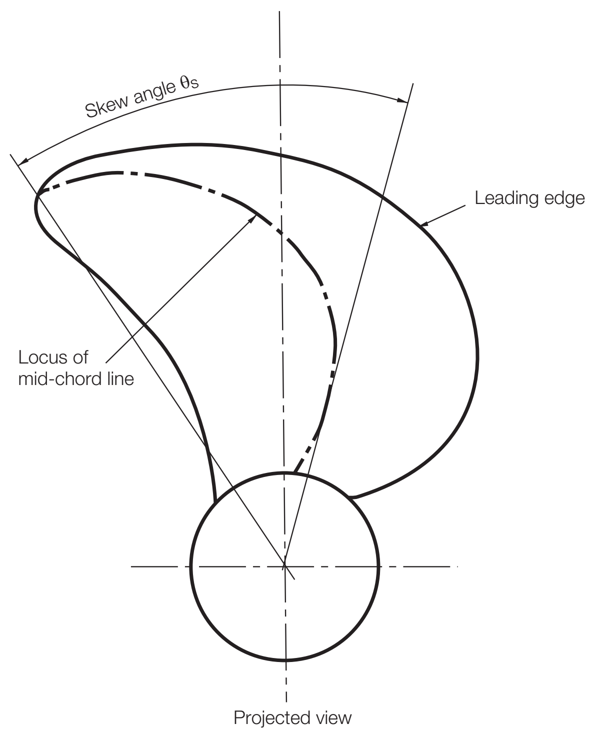


Fig. 5.1.1 Definition of skew angle

1.1.5 Where it is proposed to fit the propeller to the screwshaft without the use of a key, plans of the boss, tapered end of screwshaft, propeller nut and where applicable, the sleeve, are to be submitted.

Section 2 Materials

2.1 Castings

2.1.1 Castings for propellers and propeller blades are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials*. The specified minimum tensile strength is to be not less than stated in Table 5.2.1.

2.1.2 Where it is proposed to use materials which are not included in Table 5.2.1, details of the chemical composition, mechanical properties and density are to be submitted for approval.

Section 3 Design

3.1 Minimum blade thickness

3.1.1 For propellers having a skew angle of less than 25° as defined in 1.1.3 the minimum blade thickness, T, of the propeller blades at 25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers, neglecting any increase due to fillets, and at 60 per cent radius, is to be not less than:

$$T = \frac{KCA}{EFULN} + 95\sqrt{\frac{3150MP}{EFRULN}}\ \text{mm}$$

where L = $L_{0,25}$, $L_{0,35}$, or $L_{0,6}$, as appropriate

$K = \dfrac{GBD^3R^2}{675}$

G = density, in g/cm^3, *see* Table 5.2.1

U = allowable stress, in N/mm^2 *see* 3.1.2, 3.1.3, 3.1.4, and Table 5.2.1

$E = \dfrac{\text{actual face modulus}}{0{,}09T^2 L}$

For aerofoil sections with and without trailing edge washback, E may be taken as 1,0 and 1,25 respectively

Table 5.2.1 Materials for propellers

Material	SI units			Metric units		
	Specified minimum tensile strength N/mm^2	G Density g/cm^3	U Allowable stress N/mm^2	Specified minimum tensile strength kgf/mm^2	G Density g/cm^3	U Allowable stress kgf/mm^2
Grey cast iron	250	7,2	17,2	25	7,2	1,75
Spheroidal or nodular graphite cast iron	400	7,3	20,6	41	7,3	2,1
Carbon steels	400	7,9	20,6	41	7,9	2,1
Low alloy steels	440	7,9	20,6	45	7,9	2,1
13% chromium stainless steels	540	7,7	41	55	7,7	4,2
Chromium-nickel austenitic stainless steel	450	7,9	41	46	7,9	4,2
Duplex stainless steels	590	7,8	41	60	7,8	4,2
Grade Cu 1 Manganese bronze (high tensile brass)	440	8,3	39	45	8,3	4,0
Grade Cu 2 Ni-Manganese bronze (high tensile brass)	440	8,3	39	45	8,3	4,0
Grade Cu 3 Ni-Aluminium bronze	590	7,6	56	60	7,6	5,7
Grade Cu 4 Mn-Aluminium bronze	630	7,5	46	64	7,5	4,7

$$\left.\begin{aligned} C &= 1{,}0 \\ F &= \frac{P_{0,25}}{D} + 0{,}8 \\ M &= 1{,}0 + \frac{3{,}75D}{P_{0,7}} + 2{,}8\,\frac{P_{0,25}}{D} \end{aligned}\right\} \text{for solid propellers at 25 per cent radius}$$

$$\left.\begin{aligned} C &= 1{,}4 \\ F &= \frac{P_{0,35}}{D} + 1{,}6 \\ M &= 1{,}35 + \frac{5D}{P_{0,7}} + 2{,}6\,\frac{P_{0,35}}{D} \end{aligned}\right\} \text{for controllable pitch propellers at 35 per cent radius}$$

$$\left.\begin{aligned} C &= 1{,}6 \\ F &= \frac{P_{0,6}}{D} + 4{,}5 \\ M &= 1{,}35 + \frac{5D}{P_{0,7}} + 1{,}35\,\frac{P_{0,6}}{D} \end{aligned}\right\} \text{for all propellers at 60 per cent radius}$$

3.1.2 The fillet radius between the root of a blade and the boss of a propeller is to be not less than the Rule thickness of the blade or equivalent at this location. Composite radiused fillets or elliptical fillets which provide a greater effective radius to the blade are acceptable and are to be preferred. Where fillet radii of the required size cannot be provided, the value of U is to be multiplied by $\left(\frac{r}{R}\right)^2$

where

r = proposed fillet radius at the root, in mm

T = Rule thickness of the blade at the root, in mm

Where a propeller has bolted-on blades, consideration is also to be given to the distribution of stress in the palms of the blades. In particular, the fillets of recessed bolt holes and the lands between bolt holes are not to induce stresses which exceed those permitted at the outer end of the fillet radius between the blade and the palm.

3.1.3 For propellers having skew angles of 25° or greater, but less than 50°, the mid-chord thickness, $T_{sk0,6}$, at the 60 per cent radius is to be not less than:

$$T_{sk0,6} = 0{,}54T_{0,6}\sqrt{1 + 0{,}1\theta_s}\ \text{mm}$$

The mid-chord thickness, $T_{sk\,root}$, at 25 or 35 per cent radius, neglecting any increase due to fillets, is to be not less than:

$$T_{sk\,root} = 0{,}75T_{root}\sqrt[4]{1 + 0{,}1\theta_s}\ \text{mm}$$

where

θ_s = proposed skew angle as defined in 1.1.4

$T_{0,6}$ = thickness at 60 per cent radius calculated by 3.1.1, in mm

T_{root} = thickness at 25 per cent or 35 per cent calculated by 3.1.1, in mm

The thicknesses at the remaining radii are to be joined by a fair curve and the sections are to be of suitable aerofoil section.

3.1.4 Results of detailed calculations where carried out, are to be submitted.

3.1.5 For cases where the composition of the propeller material is not specified in Table 5.2.1, or where propellers of the cast irons and carbon and low alloy steels shown in this Table are provided with an approved method of cathodic protection, special consideration will be given to the value of U.

3.1.6 The value U may be increased by 10 per cent for twin screw and outboard propellers of triple screw ships.

3.1.7 Where the design of a propeller has been based on analysis of reliable wake survey data in conjunction with a detailed fatigue analysis and is deemed to permit scantlings less than required by 3.1.1 or 3.1.3, a detailed stress computation for the blades is to be submitted for consideration.

3.2 Keyless propellers

3.2.1 The symbols used in 3.2.2 are defined as follows:

d_1 = diameter of the screw shaft cone at the mid-length of the boss or sleeve, in mm

d_3 = outside diameter of the boss at its mid-length, in mm

d_i = bore diameter of screw shaft, in mm

k_3 = d_3 / d_1

l = d_i / d_1

$$P_1 = \frac{2\,M}{A_1\,\theta_1\,V_1}\left[-1 + \sqrt{1 + V_1\left(\frac{F_1^2}{M^2} + 1\right)}\right]$$

$$P_{10} = \frac{2\,M}{A_1\,\theta_1\,V_1} - 1 + \sqrt{1 + V_1\,\frac{F_{10}^2}{M^2} + l}$$

A_1 = contact area of fitting at screw shaft, in mm²

$$B_3 = \frac{1}{E_3}\left(\frac{k_3^2 + 1}{k_3^2 - 1} + \nu_3\right) + \frac{1}{E_1}\left(\frac{1 + l^2}{1 - l^2} - \nu_1\right)$$

C = 0 for turbine installations

$$= \frac{\text{vibratory torque at the maximum service speed}}{\text{mean torque at the maximum service speed}}$$

for oil engine installations

E_1 = modulus of elasticity of screwshaft material, in N/mm²

E_2 = modulus of elasticity of sleeve material, in N/mm²

E_3 = modulus of elasticity of propeller material, in N/mm²

$$F_1 = \frac{2000Q}{d_1}(1 + C)$$

$$F_{10} = \frac{2Q}{d_1}\left(1 + C + \frac{I_f}{100}\right)$$

I_f = percentage increase for Ice Class obtained from Chapter 7

M = propeller thrust, in N

Q = mean torque corresponding to P and R as defined in Ch 1,3.3, in Nmm

T_1 = temperature at time of fitting propeller on shaft, in °C

$V_1 = 0{,}51 \left(\frac{\mu_1}{\theta_1}\right)^2 - 1$

$\alpha 1$ = coefficient of linear expansion of screw shaft material, in mm/mm/°C

$\alpha 3$ = coefficient of linear expansion of propeller material, in mm/mm/°C

θ_1 = taper of the screwshaft cone, but is not to exceed $\frac{1}{15}$ on the diameter, i.e. $\theta_1 \le \frac{1}{15}$

μ_1 = coefficient of friction for fitting of boss assembly on shaft
= 0,13 for oil injection method of fitting

ν_1 = Poisson's ratio for screw shaft material

ν_3 = Poisson's ratio for propeller material

3.2.2 Where it is proposed to fit a keyless propeller by the oil shrink method, the pull-up, δ on the screwshaft is to be not less than:

$$\delta_T = \frac{d_1}{\theta_1} (p_1 B_3 + (\alpha_3 - \alpha_1)(35 - T_1)) \text{ mm}$$

or, where Ice Class notation is required, the greater of δ_T or δ_O, where

$$\delta_O = \frac{d_1}{\theta_1} (p_{10} B_3 - (\alpha_3 - \alpha_1)\, T_1) \text{ mm}$$

The yield stress or 0,2 per cent proof stress, σ_o of the propeller material is to be not less than:

$$\sigma_O = \frac{1{,}4}{B_3} \left(\frac{\theta_1 \delta_p}{d_1} + T_1 (\alpha_3 - \alpha_1)\right) \frac{\sqrt{3k_3^4 + 1}}{k_3^2 - 1} \text{ N/mm}^2$$

where

δ_p = proposed pull-up at the fitting temperature.

The start point load, W, to determine the actual pull-up is to be not less than:

$$W = A_1 \left(0{,}002 + \frac{\theta_1}{20}\right)\left(p_1 + \frac{18}{B_3} (\alpha_3 - \alpha_1)\right) \text{ N}$$

3.3 Keyed propellers pushed up by an hydraulic nut

3.3.1 Calculations are to be undertaken to show that the proof stress of the boss material is not exceeded in way of the keyway root fillet radius. In order to reduce the likelihood of frettage a grip stress of not less than 20 N/mm^2 between boss and shaft is to be achieved and the requirements of 4.2 and 4.3, where appropriate, are applicable.

■ *Section 4* Fitting of propellers

4.1 Propeller boss

4.1.1 The propeller boss is to be a good fit on the screwshaft cone. The forward edge of the bore of the propeller boss is to be rounded to a radius of not less than 6 mm. In the case of keyed propellers, the length of the forward fitting surface is to be about one diameter.

4.2 Shop tests of keyless propellers

4.2.1 The bedding of the propeller with the shaft, is to be demonstrated in the shop to the satisfaction of the Surveyors. Sufficient time is to be allowed for the temperature of the components to equalize before bedding. Alternative means for demonstrating the bedding of the propeller will be considered.

4.2.2 Means are to be provided to indicate the relative axial position of the propeller boss on the shaft taper.

4.3 Final fitting of keyless propellers

4.3.1 After verifying that the propeller and shaft are at the same temperature and the mating surfaces are clean and free from oil or grease, the propeller is to be fitted on the shaft to the satisfaction of the Surveyors. The propeller nut is to be securely locked to the shaft.

4.3.2 Permanent reference marks are to be made on the propeller boss, nut and shaft to indicate angular and axial positioning of the propeller. Care is to be taken in marking the inboard end of the shaft taper to minimize stress raising effects.

4.3.3 The outside of the propeller boss is to be hard stamped with the following details:

(a) For the oil injection method of fitting, the start point load and the axial pull-up at 0°C and 35°C.

(b) For the dry fitting method, the push-up load at 0°C and 35°C.

4.3.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement are to be placed on board.

■ *Scope*

The requirements of this Chapter are applicable to the following systems:

(a) Main propulsion systems formed by oil engines or electric motors, directly driven or geared to the shafting, developing 500 kW and over.

(b) Machinery driven at constant speed by oil engines, developing 500 kW and over, for essential auxiliary services including generator sets which are the source of power for main electric propulsion motors.

Unless otherwise advised, it is the responsibility of the Shipbuilder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

■ *Section 1* General

1.1 Basic requirements

1.1.1 The systems are to be free from excessive torsional, axial, lateral and linear vibration, and are to be aligned in accordance with accepted tolerances and taking into account the requirements of 5.5.

1.1.2 System designs are to take account of the potential effects of engine and component malfunction and variability in characteristic values such as stiffness and damping of flexible couplings and dampers or engine misfire conditions.

1.1.3 Where torques, stresses or amplitudes are found to exceed the limits for continuous operation, restrictions in speed and/or power will be imposed.

1.1.4 Where significant changes are subsequently made to a dynamic system which has been approved (e.g. by changing the original design parameters of the prime movers and/or propulsion shafting system or by fitting a propeller or flexible coupling of different design from the previous), revised calculations may require to be submitted for consideration. Details of all such changes are to be submitted.

1.2 Resilient mountings

1.2.1 For resilient mountings, *see* Ch 1,4.2.

■ *Section 2* Torsional vibration

2.1 General

2.1.1 In addition to the shafting complying with the requirements of Chapters 1 to 5, 16 and 17 (where applicable), approval is also dependent on the torsional vibration characteristics of the complete shafting system(s) being found satisfactory.

2.2 Particulars to be submitted

2.2.1 Torsional vibration calculations, showing the mass elastic values, associated natural frequencies and an analysis of the vibratory torques and stresses for the full dynamic system.

2.2.2 Particulars of the division of power and utilisation, throughout the speed range, for multi-engine or other combined power installations, and those with power take-off systems. For multi-engined installations, special considerations associated with the possible variations in the mode of operation and phasing of engines.

2.2.3 Details of operating conditions encountered in service for prolonged periods, e.g. idling speed, range of trawling revolutions per minute, combinator characteristics for installations equipped with controllable pitch propellers.

2.2.4 Details, obtained from the manufacturers, of the principal characteristics of machinery components such as dampers and couplings, confirming their capability to withstand the effects of vibratory loading including, where appropriate, heat dissipation. Evidence that the data which is used to represent the characteristics of components, which has been quoted from other sources, is supported by a programme of physical measurement and control.

2.2.5 Where installations include electric motors, generators or non-integral pumps, drawings showing the principal dimensions of the shaft, together with manufacturer's estimates of mass moment of inertia for the rotating parts.

2.2.6 Details of vibration or performance monitoring proposals where required.

2.3 Scope of calculations

2.3.1 Calculations are to be carried out, by recognised techniques, for the full dynamic system formed by the oil engines, motors, generators, flexible couplings, gearing, shafting and propeller, where applicable, including all branches.

2.3.2 Calculations are to give due consideration to the potential deviation in values used to represent component characteristics due to manufacturing/service variability.

2.3.3 The calculations carried out on oil engine systems are to be based on the Enginebuilder's harmonic torque data. (On request, Lloyd's Register (hereinafter referred to as LR) can provide a table of generalised harmonic torque components for use where appropriate.) The calculations are to take account of the effects of engine malfunction commonly experienced in service, such as a cylinder not firing. Calculations are also to take account of a degree of imbalance between cylinders, which is characteristic of the normal operation of an engine under service conditions.

2.3.4 Whilst limits for torsional vibration stress in crankshafts are no longer stated explicitly, calculations are to include estimates of crankshaft stress at all designated operating/service speeds, as well as at any major critical speed.

2.3.5 Calculations are to take into account the possible effects of excitation from propeller rotation. Where the system shows some sensitivity to this phenomenon, propeller excitation data for the installation should be used as a basis for calculation, and submitted.

2.3.6 Where the torsional stiffness of flexible couplings varies with torque, frequency or speed, calculations should be representative of the appropriate range of effective dynamic stiffness.

2.4 Symbols and definitions

2.4.1 The symbols used in this Section are defined as follows:

d = minimum diameter of shaft considered, in mm
d_i = diameter of internal bore, in mm
k = the factor used in determining minimum shaft diameter, defined in Ch 4,3.2.1 and 3.4.2
r = ratio N/N_s or N_c/N_s whichever is applicable
C_d = a size factor defined as $0{,}35 + 0{,}93d^{-0{,}2}$
C_k = a factor for different shaft design features, *see* Table 6.2.1
N = engine speed, in rev/min
N_c = critical speed, in rev/min
N_s = maximum continuous engine speed, in rev/min, or, in the case of constant speed generating sets, the full load speed, in rev/min
Q_s = rated full load mean torque, kNm
σ_u = specified minimum tensile strength of the shaft material, in N/mm^2
τ_c = permissible stress due to torsional vibrations for continuous operation, in N/mm^2
τ_t = permissible stress due to torsional vibrations for transient operation, in N/mm^2
e = slow width, in mm
l = slot length, in mm.

2.4.2 Alternating torsional vibration stresses are to be based on half-range amplitudes of stress resulting from the alternating torque (which is superimposed on the mean torque) representing the synthesis of all harmonic orders present.

2.4.3 All vibration stress limits relate to the synthesis or measurement of total nominal torsional stress and are to be based on the plain section of the shafting neglecting stress raisers.

2.4.4 For a longitudinal slot, C_k = 0,3 is applicable within the dimension limitations given in Pt 5, Ch 6,3.1.6 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships). If the slot dimensions are outside these limitations, or if the use of an other C_k is desired, the actual stress concentration factor (*scf*) is to be documented or determined from 2.4.5, in which case:

$$C_K = \frac{145}{scf}$$

NOTE
The *scf* is defined as the ratio between the maximum local principal stress and $\sqrt{3}$ times the nominal torsional stress (determined for the bored shaft without slots).

Table 6.2.1 C_k factors

Intermediate shafts with						Thrust shafts external to engines		Propeller shafts		
Integral coupling flanges and straight sections	Shrink-fit coupling	Keyway, tapered connection	Keyway, cylindrical connection	Radial hole	Longitudinal slot	On both sides of thrust collar	In way of axial bearing where a roller bearing is used as a thrust bearing	Flange mounted or keyless tapered fitted propellers	Key fitted propellers	Between forward end of aft most bearing and forward stern tube seal
1,0	1,0	0,60	0,45	0,50	0,30 (*see* 2.4.4)	0,85	0,85	0,55	0,55	0,80

NOTE
The determination of C_k factors for shafts other than shown in this Table will be specially considered by LR.

2.4.5 **Stress concentration factor of slots.** The stress concentration factor (*scf*) at the end of the slots can be determined by means of the following empirical formulae:
This formula applies to:

$$scf = \alpha_t(hole) + 0{,}57 \times \frac{\frac{(l - e)}{d}}{\sqrt{\left(1 - \frac{d_i}{d}\right) \times \frac{e}{d}}}$$

- Slots at 120 or 180 or 360 degrees apart
- Slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula.
- Slots with no edge rounding (except chamfering), as any edge rounding increases the *scf* slightly

$\alpha_t(hole)$ represents the stress concentration of radial holes and can be determined as:

$$\alpha_t(hole) = 2{,}3 - 3 \times \frac{e}{d} + 15 \times \left(\frac{e}{d}\right)^2 + 10 \times \left(\frac{e}{d}\right)^2 \times \left(\frac{d_i}{d}\right)^2$$

where

e = hole diameter, in mm or simplified to $\alpha_t(hole) = 2{,}3$.

2.5 Limiting stress in propulsion shafting

2.5.1 The following stress limits apply to intermediate shafts, thrust shafts and to screwshafts fully protected from outboard water. For screwshafts, the limits apply to the minimum sections of the portions of the screwshaft as defined in Ch 4,3.4.

2.5.2 In the case of unprotected screwshafts, special consideration will be given.

2.5.3 In no part of the propulsion shafting system may the alternating torsional vibration stresses exceed the values of τ_c for continuous operation, and τ_t for transient running, given by the following formulae:

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d (3 - 2r^2) \text{ for } r < 0{,}9 \text{ N/mm}^2$$

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d \, 1{,}38 \text{ for } 0{,}9 \le r \le 1{,}05 \text{ N/mm}^2$$

$$\tau_t = \pm 1{,}7\tau_c \frac{1}{\sqrt{C_k}} \text{ for } r \le 0{,}8 \text{ N/mm}^2$$

2.5.4 In general, the tensile strength of the steel used is to comply with the requirements of Ch 4,2. For the calculation of the permissible limits of stresses due to torsional vibration, σ_u is not to be taken as more than 800 N/mm² in the case of alloy steel intermediate shafts, or 600 N/mm² in the case of carbon-manganese steel intermediate thrust and propeller shafts.

2.5.5 Where the scantlings of coupling bolts and straight shafting differ from the minimum required by the Rules, special consideration will be given.

2.6 Generator sets

2.6.1 Natural frequencies of the complete set are to be sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator.

2.6.2 Within the speed limits of $0{,}95N_s$ and $1{,}05N_s$ the vibration stresses in the transmission shafting are not to exceed the values given by the following formula:

$$\tau_c = \pm (21 - 0{,}014d) \text{ N/mm}^2$$

2.6.3 Vibration stresses in the transmission shafting due to critical speeds which have to be passed through in starting and stopping, are not to exceed the values given by the following formula:

$$\tau_t = 5{,}5\tau_c \text{ N/mm}^2$$

2.6.4 The amplitudes of the total vibratory inertia torques imposed on the generator rotors are to be limited to $\pm 2{,}0Q_s$ in general, or to $\pm 2{,}5Q_s$ for close-coupled revolving field alternating current generators, over the speed range from $0{,}95N_s$ to $1{,}05N_s$. Below $0{,}95N_s$ the amplitudes are to be limited to $\pm 6{,}0Q_s$. Where two or more generators are driven from one engine, each generator is to be considered separately in relation to its own rated torque.

2.6.5 The rotor shaft and structure are to be designed to withstand these magnitudes of vibratory torque. Where it can be shown that they are capable of withstanding a higher vibratory torque, special consideration will be given.

2.6.6 In addition to withstanding the vibratory conditions over the speed range from $0{,}95N_s$ to $1{,}05N_s$ flexible couplings, if fitted, are to be capable of withstanding the vibratory torques and twists arising from transient criticals and short-circuit currents.

2.6.7 In the case of alternating current generators, resultant vibratory amplitudes at the rotor are not to exceed ±3,5 electrical degrees under both full load working conditions and the malfunction condition mentioned in 2.3.3.

2.7 Other auxiliary machinery systems

2.7.1 The relevant requirements of 2.6.1, 2.6.2 and 2.6.3 are also applicable to other machinery installations such as pumps or compressors with the speed limits being taken as $0{,}95N_s$ to $1{,}10N_s$.

2.8 Other machinery components

2.8.1 **Torsional vibration dampers.** The use of dampers or detuners to limit vibratory stress due to resonances which occur within the range between $0{,}85N_s$ and $1{,}05N_s$ are to be considered. If fitted, these should be of a type which makes adequate provision for dissipation of heat. Where necessary, performance monitoring may be required.

2.8.2 **Flexible couplings:**

(a) Flexible couplings included in an installation are to be capable of transmitting the mean and vibratory loads without exceeding the maker's recommended limits for angular amplitude or heat dissipation.

(b) Where calculations indicate that the limits recommended by the manufacturer may be exceeded under misfiring conditions, a suitable means is to be provided for detecting and indicating misfiring. Under these circumstances power and/or speed restriction may be required. Where machinery is non-essential, disconnection of the branch containing the coupling would be an acceptable action in the event of misfiring.

2.8.3 **Gearing:**

(a) The torsional vibration characteristics are to comply with the requirements of 2.3. The sum of the mean and of the vibratory torque should not exceed four-thirds of the full transmission torque, at MCR, throughout the speed range. In cases where the proposed transmission torque loading on the gear teeth is less than the maximum allowable, special consideration will be given to the acceptance of additional vibratory loading on the gears.

(b) Where calculations indicate the possibility of torque reversal, the operating speed range is to be determined on the basis of observations during sea trials.

2.9 Measurements

2.9.1 Where calculations indicate that the limits for torsional vibration within the range of working speeds are exceeded, measurements, using an appropriate technique, may be taken from the machinery installation for the purpose of approval of torsional vibration characteristics, or determining the need for restricted speed ranges, and the confirmation of their limits.

2.9.2 Where differences between calculated and measured levels of stress, torque or angular amplitude arise, the stress limits are to be applied to the stresses measured on the completed installation.

2.9.3 The method of measurement is to be appropriate to the machinery components and the parameters which are of concern. Where shaft stresses have been estimated from angular amplitude measurements, and are found to be close to limiting stresses as defined in 2.5, strain gauge techniques may be required. When measurements are required, detailed proposals are to be submitted.

2.10 Vibration monitoring

2.10.1 Where calculations and/or measurements have indicated the possibility of excessive vibratory stresses, torques or angular amplitudes in the event of a malfunction, vibration or performance monitoring, directly or indirectly, may be required.

2.11 Restricted speed and/or power ranges

2.11.1 Restricted speed and/or power ranges will be imposed where the stresses exceed the limiting values, τ_c, for continuous running. Similar restrictions will be imposed, or other protective measures required to be taken, where vibratory torques or amplitudes are considered to be excessive for particular machinery items.

2.11.2 Critical responses which give rise to speed restrictions are to be arranged sufficiently removed from the maximum revolutions per minute to ensure that, in general, at r = 0,8 the stress due to the upper flank does not exceed τ_c.

2.11.3 Where shafting stresses due to a torsional critical response exceed the limiting values, τ_c, for continuous running, the speed restriction will be from:

$$\frac{16}{18-r} N_c \text{ to } \frac{18-r}{16} N_c \text{ inclusive}$$

2.11.4 Where calculated vibration stresses due to criticals below $0{,}8N_s$ marginally exceed τ_c or where the critical speeds are sharply tuned, the range of revolutions restricted for continuous operation may be reduced.

2.11.5 In cases where the resonance curve of a critical speed has been derived from measurements, the range of revolutions to be avoided for continuous running may be taken as that over which the measured vibration stresses are in excess of τ_c, having regard to the tachometer accuracy.

2.11.6 Where restricted speed ranges under normal operating conditions are imposed, notice boards are to be fitted at the control stations stating that the engine is not to be run continuously between the speed limits obtained as above, and the engine tachometers are to be marked accordingly.

2.11.7 Where vibration stresses approach the limiting value, τ_t, the range of revolutions restricted for continuous operation may be extended. The notice boards are to indicate that this range must be passed through rapidly.

2.11.8 For excessive vibratory torque, stress or amplitude in other components, based on 2.8.1 to 2.8.3, the limits of any speed/power restriction are to be such as to maintain acceptable levels during continuous operation.

2.11.9 Where restrictions are imposed for the contingency of an engine malfunction or component failure, the limits are to be entered in the machinery operating manual.

2.12 Tachometer accuracy

2.12.1 Where restricted speed ranges are imposed as a condition of approval, the tachometer accuracy is to be checked against the counter readings, or by equivalent means, in the presence of the Surveyor to verify that it reads correctly within ±2 per cent in way of the restricted range of revolutions.

2.13 Governor control

2.13.1 Where there is a significant critical response above and close to service speed, consideration is to be given to the effect of temporary overspeed.

■ *Section 3* Axial vibration

3.1 General

3.1.1 For all main propulsion shafting systems, the Shipbuilders are to ensure that axial vibration amplitudes are satisfactory throughout the speed range. Where natural frequency calculations indicate significant axial vibration responses, sufficiently wide restricted speed ranges will be imposed. Alternatively, measurements may be used to determine the speed ranges at which amplitudes are excessive for continuous running.

3.2 Particulars to be submitted

3.2.1 The results of calculations, together with recommendations for any speed restrictions found necessary.

3.2.2 Engine Builder's recommendation for axial vibration amplitude limits at the non-driving end of the crankshaft or at the thrust collar.

3.2.3 Estimate of flexibility of the thrust bearing and its supporting structure.

3.2.4 The requirement for calculations to be submitted may be waived upon request provided evidence of satisfactory service experience of similar dynamic installations is submitted.

3.3 Calculations

3.3.1 Calculations of axial vibration natural frequency are to be carried out using appropriate techniques, taking into account the effects of flexibility of the thrust bearing, for shaft systems where the propeller is:

(a) Driven directly by a reciprocating internal combustion engine.

(b) Driven via gears, or directly by an electric motor, and where the total length of shaft between propeller and thrust bearing is in excess of 60 times the intermediate shaft diameter.

3.3.2 Where an axial vibration damper is fitted, the calculations are to consider the effect of a malfunction of the damper.

3.3.3 For those systems as defined in 3.3.1, the propeller speed at which the critical frequency occurs may be estimated using the following formula:

$$n_c = \frac{0{,}98}{N}\left(\frac{ab}{a+b}\right)^{1/2} \text{ (rev/min)}$$

where

$$a = \frac{E}{Gl^2}(66{,}2 + 97{,}5A - 8{,}88A^2)^2 \text{ (c/min)}^2$$

$$b = 91{,}2\,\frac{k}{M_e} \text{ (c/min)}^2$$

d = internal diameter of shaft, in mm
k = estimated stiffness at thrust block bearing, in N/m
l = length of shaft line between propeller and thrust bearing, in mm
m = mass of shaft line considered, in kg
= $0{,}785\,(D^2 - d^2)\,Gl$
n_c = propeller speed at which critical frequency occurs, in rev/min
A = $\dfrac{m}{M}$
D = outside diameter of shaft, taken as an average over length, l, in mm
E = modulus of elasticity of shaft material, in N/mm^2
G = density of shaft material, in kg/mm^3
M = dry mass of propeller, in kg
M_e = $M\,(A + 2)$
N = number of propeller blades

Where the results of this method indicate the possibility of an axial vibration resonance in the vicinity of service speed, calculations using a more accurate method will be required.

3.4 Measurements

3.4.1 Where calculations indicate the possibility of excessive axial vibration amplitudes within the range of working speeds under normal or malfunction conditions, measurements are required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

3.5 Restricted speed ranges

3.5.1 The limits of any speed restriction are to be such as to maintain axial amplitudes within recommended levels during continuous operation.

3.5.2 Limits of a speed restriction, where required, may be determined by calculation or on the basis of measurement.

3.5.3 Where a speed restriction is imposed for the contingency of a damper malfunction, the speed limits are to be entered in the machinery operating manual and regular monitoring of the axial vibration amplitude is required. Details of proposals for monitoring are to be submitted.

3.6 Vibration monitoring

3.6.1 Where a vibration monitoring system is to be specified, details of proposals are to be submitted.

■ *Section 4* Lateral vibration

4.1 General

4.1.1 Long unsupported lengths of main propulsion shafting are to be avoided by the fitting of steady bearings at suitable positions. In determining these positions, the Shipbuilder is to ensure that no harmful lateral vibrations are present throughout the speed range, so far as is practicable.

4.2 Particulars to be submitted

4.2.1 Calculations of the lateral vibration characteristics of shafting systems incorporating cardan shafts are to be submitted.

4.3 Calculations

4.3.1 The calculations in 4.2.1, taking account of bearing, oil-film (where applicable) and structural dynamic stiffnesses, are to investigate the excitation frequencies giving rise to all critical speeds which may result in significant amplitudes within the speed range, and are to indicate relative deflections and bending moments throughout the shafting system.

4.3.2 Requirements for calculations may be waived upon request, provided evidence of satisfactory service experience of similar dynamic installations is submitted.

4.3.3 For cardan shafts fitted in the high speed part of thruster drives, lateral vibration calculations are only required for the high speed part of the installation i.e. it is not mandatory to carry out lateral vibration calculations for the complete dynamic system.

4.4 Measurements

4.4.1 Where calculations indicate the possibility of significant lateral vibration responses within the range of ±20 per cent of the M.C.R. speed, measurements using an appropriate recognized technique may be required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

4.4.2 The method of measurement is to be appropriate to the machinery arrangement and the modes of vibration which are of concern. When measurements are required, detailed proposals are to be submitted in advance.

■ *Section 5* Shaft alignment

5.1 General

5.1.1 The Builder is to carry out shaft alignment calculations for all installations and to prepare alignment procedures detailing the proposed alignment method and the alignment checks.

5.2 Particulars to be submitted for approval – shaft alignment calculations

5.2.1 Shaft alignment calculations are to be submitted to LR for approval for the following shafting systems where the screwshaft has a diameter of 300 mm or greater in way of the aftermost sterntube bearing:

(a) all geared installations;
(b) installations with one shaftline bearing, or less, inboard of the forward sterntube bearing/seal;
(c) where prime movers or shaftline bearings are installed on resilient mountings.

5.2.2 The shaft alignment calculations are to take into account the:

(a) thermal displacements of the bearings between cold static and hot dynamic machinery conditions;
(b) buoyancy effect of the propeller immersion due to the ship's operating draughts;
(c) effect of predicted hull deformations over the range of the ship’s operating draughts, where known;
(d) gear forces, where appropriate;
(e) for multi-engined installations, possible contributions in the mode of operation;
(f) propeller offset thrust effects, where applicable;
(g) bearing loading in the horizontal plane, where appropriate; and
(h) bearing weardown, where applicable, and its effect on the bearing loads.

5.2.3 The shaft alignment calculations are to state the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the ship's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) bearing influence coefficients and the deflection, slope, bending moment and shear force along the shaftline;
(c) details of propeller offset thrust effects, where employed in calculation;
(d) details of proposed slope-bore of the aftermost sterntube bearing, where applicable;
(e) manufacturer's specified limits for bending moment and shear force at the shaft couplings of the gearbox/prime movers;
(f) estimated bearing weardown rates for water or grease-lubricated sterntube bearings;
(g) origin of findings where the effect of hull deformation has been considered, *viz*. whether finite element calculations or measured results from sister or similar ships have been used;

(h) anticipated thermal rise of prime movers and gearing units between cold static and hot running conditions; and
(j) manufacturer's allowable bearing loads.

5.3 Particulars to be submitted for review – Shaft alignment procedure

5.3.1 A shaft alignment procedure is to be submitted for all main propulsion installations detailing, as a minimum, the:
(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the ship's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) maximum permissible loads for the proposed bearing designs;
(c) design bearing offsets from the straight line;
(d) design gaps and sags;
(e) location and loads for the temporary shaft supports;
(f) expected relative slope of the shaft and the bearing in the aftermost sterntube bearing;
(g) details of slope-bore of the aftermost sterntube bearing, where applied;
(h) expected shear forces and bending moments at the forward end flange of the shafting system connecting to the gear output shaft or, for direct-drive installations, to the prime mover output flange;
(j) proposed bearing load measurement technique and its estimated accuracy;
(k) jack correction factors for each bearing where the bearing load is measured using a specified jacking technique;
(l) proposed shaft alignment acceptance criteria, including the tolerances; and
(m) flexible coupling alignment criteria.

5.4 Design and installation criteria

5.4.1 For main propulsion installations, the shafting is to be aligned to give, in all conditions of ship loading and machinery operation, bearing load distribution satisfying the requirements of 5.4.2.

5.4.2 Design and installation of the shafting is to satisfy the following criteria:
(a) The Builder is to position the bearings and construct the bearing seatings to minimize the effects of hull deflections under any of the ship's operating conditions.
(b) Relative slope between the propeller shaft and the aftermost sterntube bearing is, in general, not to exceed 3×10^{-4} rad.
(c) Sterntube bearing loads are to satisfy the requirements of Ch 4,3.12.
(d) Intermediate shaft bearings' loads are not to exceed 80 per cent of the bearing manufacturer's allowable maximum load, for plain journal bearings, based on the bearing projected area.
(e) Main gear wheel bearing loads are to be within the gearbox manufacturer's specified limits.
(f) Resulting shear forces and bending moments are to meet the equipment manufacturer's specified coupling conditions throughout the shafting system.
(g) The manufacturer's radial, axial and angular alignment limits for the flexible couplings are to be maintained.

5.5 Measurements

5.5.1 Where calculations indicate that the system is sensitive to changes in alignment under different service conditions, the optimized shaft alignment is to be verified by measurements during sea trials using an approved strain gauge technique.

5.6 Flexible couplings

5.6.1 Where the shafting system incorporates flexible couplings, the effects of such couplings on the various modes of vibration are to be considered, *see* Sections 2, 3 and 4.

Section 1
General service

1.1 General

1.1.1 Where the notation 'Ice' as specified in Pt 1, Ch 2 is desired, the following requirements are to be complied with, so far as these are applicable.

1.2 Materials for shafting

1.2.1 All components of the main propulsion system are to be of steel or other approved material.

1.3 Materials for propellers

1.3.1 Propellers and propeller blades are to be of cast steel or copper alloys having specified minimum tensile strengths as stated in Table 5.2.1 in Chapter 5.

1.4 Main engine shafting and propellers

1.4.1 The diameter of the screwshaft as required by Ch 4,3.4 is to be increased by five per cent.

1.4.2 The thickness of the propeller blades at the root and at 60 per cent radius as required by Ch 5,3.1 are to be increased by eight per cent.

1.4.3 The tip thickness, *t*, of the blade at 95 per cent radius is to be not less than that obtained by the following formula:

$$t = 0{,}14(T + 57)\sqrt[3]{\frac{430}{\sigma_u}} \text{ mm}$$

where

T = blade root thickness required, in mm

σ_u = specified minimum tensile strength of material, in N/mm^2

1.4.4 For keyless propellers the mean torque *Q* as defined in Ch 5,3.2 is to be increased by 15 per cent.

Cross-references

For hull requirements, *see* Part 3.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and their mountings and fittings, for the following uses:

(a) Production or storage of steam.

(b) Heating of pressurized hot water above 120°C.

(c) Heating of pressurized thermal liquid.

Seamless pressure vessels are to be manufactured and tested in accordance with the requirements of Chapter 5 of the *Rules for the Manufacture, Testing and Certification of Materials* .

1.1.2 The scantlings of coil type heaters with pumped circulation, which are fired or heated by exhaust gas are to comply with the appropriate requirements of this Chapter.

1.2 Plans

1.2.1 Plans of boilers, having working pressures exceeding 3,4 bar and having heating surfaces greater than 4,65 m^2 are to be submitted in triplicate for approval before construction is commenced.

1.2.2 These plans should give full constructional features of fusion welded pressure vessels and dimensional details of the weld preparation for longitudinal and circumferential seams and attachments, together with particulars of the welding consumables and of the mechanical properties of the materials.

1.2.3 Boiler Manufacturers are referred to in Pt 5, Ch 10 of the *Rules and Regulations for the Classification of Ships,* which contain detailed requirements for the materials, the manufacture and testing of boilers.

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and plate heat exchangers, intended for marine purposes but not for steam raising plant. The equations of this Chapter may be used for determining the thickness of seamless pressure vessels using a joint factor of 1,0. Seamless pressure vessels are to be manufactured and tested in accordance with the requirements of Chapter 5 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). For design requirements of pressure vessels intended for the carriage of liquefied gases, *see* Chapter 13.

1.1.2 Where the required design criteria for pressure vessels are not indicated within this Chapter, the relevant Sections of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) Pt 5, Ch 10 are applicable.

1.1.3 Seamless pressure vessels are to be manufactured in accordance with the requirements of the Rules for Materials where applicable.

1.2 Definition of symbols

1.2.1 The symbols used in the various formulae in Sections 2 to 6 inclusive, unless otherwise stated, are defined as follows, and are applicable to the specific part of the pressure vessel under consideration:

d = diameter of hole or opening, in mm
p = design pressure, in bar, *see* 1.3
r_i = inside knuckle radius, in mm
r_o = outside knuckle radius, in mm
t = minimum thickness, in mm
D_i = inside diameter, in mm
D_o = outside diameter, in mm
J = joint factor applicable to welded seams, *see* 1.9
R_i = inside radius, in mm
R_o = outside radius, in mm
T = design temperature, in °C
σ = allowable stress, in N/mm^2, *see* 1.8.

1.2.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.3 Design pressure

1.3.1 The design pressure is the maximum permissible working pressure, and is to be not less than the highest set pressure of any relief valve.

1.3.2 The calculations made to determine the scantlings of the pressure parts are to be based on the design pressure, adjusted where necessary to take account of pressure variations corresponding to the most severe operational conditions.

1.3.3 It is desirable that there should be a margin between the normal pressure at which the pressure vessel operates and the lowest pressure at which any relief valve is set to lift, to prevent unnecessary lifting of the relief valve.

1.4 Metal temperature

1.4.1 The metal temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.4.2 The design temperature, T, for calculation purposes is to be not less than 50°C.

1.5 Classification of fusion welded pressure vessels

1.5.1 For Rule purposes, pressure vessels are graded as Class 1 where the shell thickness exceeds 38 mm.

1.5.2 For Rule purposes, pressure vessels are graded as Class 2/1 and Class 2/2 if they comply with the following conditions:

(a) where the design pressure exceeds 17,2 bar; or
(b) where the metal temperature exceeds 150°C; or
(c) where the design pressure, in bar, multiplied by the actual thickness of the shell, in mm, exceeds 157; or
(d) where the shell thickness does not exceed 38 mm.

1.5.3 For Rule purposes, Class 3 pressure vessels are to have a maximum shell thickness of 16 mm, and are pressure vessels not included in Class 1, 2/1 or 2/2.

1.5.4 Pressure vessels which are constructed in accordance with Class 2/1, 2/2 or 3 standards (as indicated in 1.5.2 and 1.5.3) will, if manufactured in accordance with the requirements of a superior Class, be approved with the scantlings appropriate to that Class.

1.5.5 Pressure vessels which only have circumferential fusion welded seams, will be considered as seamless with no Class being assigned. Preliminary weld procedure tests and non-destructive examination for the circumferential seam welds should be carried out for the equivalent Class as determined by 1.5.1, 1.5.2 and 1.5.3.

1.5.6 In special circumstances relating to service conditions, materials, operating temperature, the carriage of dangerous gases and liquids, etc., it may be required that certain pressure vessels be manufactured in accordance with the requirements of a superior Class.

1.5.7 Heat treatment, non-destructive and routine tests where required, for the four Classes of fusion welded pressure vessel are indicated in Table 9.1.1. Details of these requirements are given in Chapter 14.

1.6 Plans

1.6.1 Plans of pressure vessels are to be submitted in triplicate for consideration where all the conditions in (a) or (b) are satisfied:

(a) The vessel contains vapours or gases, e.g. air receivers, hydrophore or similar vessels and gaseous CO_2 vessels for fire-fighting, and
$pV > 600$
$p > 1$
$V > 100$
V = volume (litres) of gas or vapour space

(b) The vessel contains liquefied gases for fire-fighting or flammable liquids, and
$p > 7$
$V > 100$
V = volume (litres)
p is as defined in 1.2.1.

1.6.2 Plans of full constructional features of the vessel and dimensional details of the weld preparations for longitudinal and circumferential seams and attachments, together with particulars of the welding consumables and of the mechanical properties of the materials, are to be submitted before construction is commenced.

1.7 Materials

1.7.1 Materials used in the construction of Class 1, 2/1 and 2/2 pressure vessels are to be manufactured, tested and certified in accordance with the requirements of the Rules for Materials. Materials used in the construction of Class 3 pressure vessels may be in accordance with the requirements of an acceptable national or international specification. The manufacturer's certificate will be accepted in lieu of LR's material certificate for such materials.

1.7.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the general limits of 340 to 520 N/mm^2.

1.7.3 The specified minimum tensile strength of low alloy steel plates, pipes, forgings and castings is to be within the general limits of 400 to 500 N/mm^2, and pressure vessels made in these steels are to be either seamless or Class 1 fusion welded.

1.7.4 Where it is proposed to use materials other than those specified in the Rules for Materials, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases, the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by LR.

1.8 Allowable stress

1.8.1 The term 'allowable stress', σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

Table 9.1.1 Heat treatment, non-destructive examination and testing requirements

Class	Radiographic examination	Heat treatment	Routine weld tests	Hydraulic test
1	Required, *see* Chapter 14	*see* Chapter 14	Required	Required
2/1	Spot required, *see* Chapter 14	*see* Chapter 14	Required	Required
2/2	—	*see* Chapter 14	Required	Required
3	—	—	—	Required

1.8.2 The allowable stress, σ, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5} \qquad \sigma = \frac{R_{20}}{2,7}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature T for carbon and carbon-manganese steels. In the case of austenitic steels, the 1,0 per cent proof stress at temperature, T, is to be used

R_{20} = specified minimum tensile strength at room temperature

T = metal temperature, *see* 1.4.

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in 1.8.2 using the appropriate values for cast steel.

1.8.4 Where steel castings, which have been tested in accordance with the Rules for Materials are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in 1.8.3. Particulars of the non-destructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in Sections 2 and 3. Fusion welded pressure parts are to be made in accordance with Chapter 14.

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75
Class 3	0,60

1.9.2 The longitudinal joints for all Classes of vessels are to be butt joints. Circumferential joints for Class 1 vessels are also to be butt welds. Circumferential joints for Class 2/1, 2/2 and 3 vessels should also be butt joints with the following exceptions:

(a) Circumferential joints for Class 2/1, 2/2 and 3 vessels may be of the joggle type provided neither plate at the joints exceeds 16 mm thickness.

(b) Circumferential joints for Class 3 vessels may be of the lap type provided neither plate at the joint exceeds 16 mm thickness nor the internal diameter of the vessel exceeds 610 mm.

For typical acceptable methods of attaching dished ends, see Fig. 9.6.1.

1.9.3 Where a pressure vessel is to be made of alloy steel, particulars of the welding consumables to be used, including typical mechanical properties and chemical composition of the deposited weld metal, are to be submitted for approval.

1.10 Adverse working conditions

1.10.1 Where working conditions are adverse, special consideration may require to be given to increasing the scantlings derived from the formulæ. In this connection, where necessary, account should also be taken of any excess loading resulting from:

(a) Impact loads, including rapidly fluctuating pressures.

(b) Weight of the vessel and normal contents under operating and test conditions.

(c) Superimposed loads, such as other pressure vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping.

(d) Reactions of supporting lugs, rings, saddles or other types of supports, or

(e) The effect of temperature gradients on maximum stress.

1.11 Pressure parts of irregular shape

1.11.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of the formulae in Sections 2 to 7, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by an agreed alternative method.

■ *Section 2* Cylindrical shells and drums subject to internal pressure

2.1 Minimum thickness

2.1.1 The minimum thickness, t, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{pR_i}{10\sigma J - 0,5p} + 0,75 \text{ mm}$$

where

t, p, R_i and σ are as defined in 1.2

J = the joint factor of the longitudinal joints (expressed as a fraction), *see* 1.9. In the case of seamless shells clear of openings J = 1,0.

2.1.2 The formula in 2.1.1 is applicable only where the resulting thickness does not exceed half the internal radius, i.e. where R_o is not greater than 1,5 R_i.

2.1.3 Irrespective of the thickness determined by the formula in 2.1.1, t is to be not less than $3 + \frac{D_i}{1500}$ mm, where D_i is as defined in 1.2.

2.1.4 The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

2.2 Unreinforced openings

2.2.1 The maximum diameter, *d*, of any unreinforced isolated opening is to be determined by the following formula:

$$d = 8{,}08\,[D_o\,t\,(1 - K)]^{1/3}\ \text{mm}$$

The value of *K* to be used is calculated from the following formula:

$$K = \frac{pD_o}{18{,}2\sigma t} \quad \text{but is not to be taken as greater than 0,99}$$

where

p, D_o and σ are as defined in 1.2

t = actual thickness of shell, in mm.

2.2.2 For elliptical or oval holes, *d* for the purposes of 2.2.1, refers to the major axis when this lies longitudinally or to the mean of the major and minor axes when the minor axis lies longitudinally.

2.2.3 No unreinforced opening is to exceed 200 mm in diameter.

2.2.4 Holes may be considered isolated if the centre distance between two holes on the longitudinal axis of a cylindrical shell is not less than:

$$d + 1{,}1\sqrt{Dt} \quad \text{with a minimum } 5d$$

where

d = diameter of openings in shell (mean diameter if dissimilarly sized holes involved)

D = mean diameter of shell

t = actual thickness of shell

Where the centre distance is less than so derived, the holes are to be fully compensated.

2.3 Reinforced openings

2.3.1 Openings larger than those permitted by 2.2 are to be compensated in accordance with Fig. 9.2.1(a) or (b). The following symbols are used in Fig. 9.2.1(a) and (b):

d_o = diameter of hole in shell, in mm

t_a = actual thickness of shell plate without corrosion allowance, in mm

t_b = actual thickness of standpipe without minus tolerances and corrosion allowance, in mm

t_d = thickness calculated in accordance with 7.1 without corrosion allowance, in mm

t_r = thickness of added reinforcement, in mm

t_s = calculated thickness of a shell without joint or opening or corrosion allowance, in mm

$C = \sqrt{d_o\,t_b}$ in mm

$D = \sqrt{D_i\,t_a}$ and is not to exceed $0{,}5d_o$, in mm

D_i = internal diameter of cylindrical shell, in mm

L = width of added reinforcement not exceeding D, in mm

σ = shell plate allowable stress, in N/mm^2

σ_p = standpipe allowable stress, in N/mm^2

σ_r = added reinforcement allowable stress, in N/mm^2

σ_w = weld metal allowable stress, in N/mm^2

NOTE

σ_p, σ_r and σ_w are not to be taken as greater than σ.

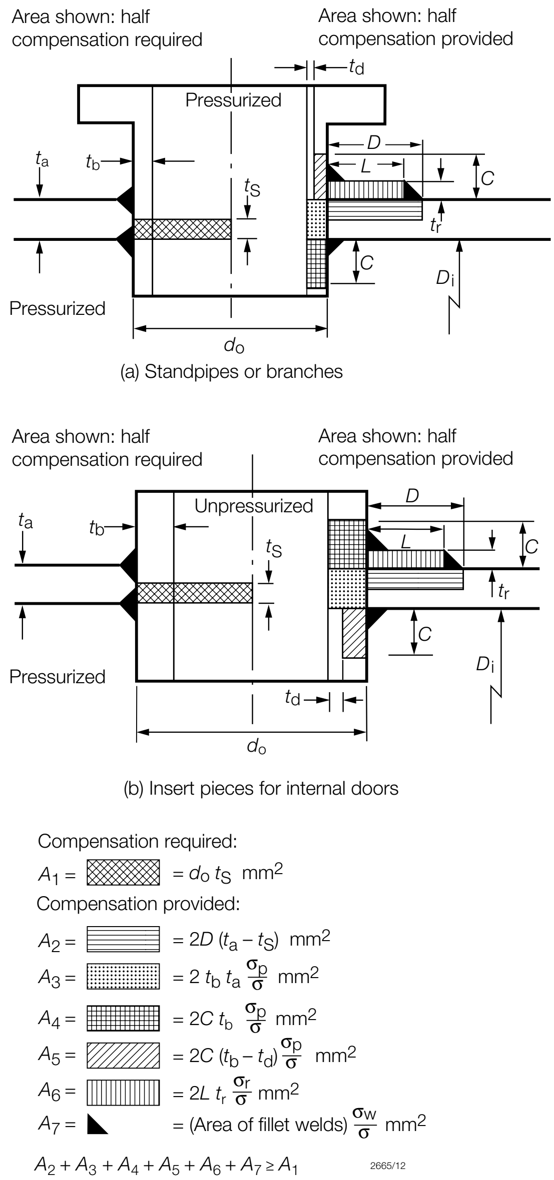


Fig. 9.2.1
Compensation for welded standpipes or branches in cylindrical shells

2.3.2 For elliptical or oval holes, the dimension on the meridian of the shell is to be used for d_o in 2.3.1.

2.3.3 The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.

2.3.4 Compensation is to be distributed equally on either side of the centreline of the opening.

Section 3 Dished ends subject to internal pressure

3.1 Minimum thickness

3.1.1 The thickness, t, of semi-ellipsoidal and hemispherical unstayed ends, and the knuckle section of torispherical ends, dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{pD_oK}{20\sigma J} + 0{,}75 \quad \text{mm}$$

where

t, p, D_o, σ and J are as defined in 1.2

K = a shape factor, *see* 3.2 and Fig. 9.3.1.

3.1.2 For semi-ellipsoidal ends:

the external height, $H \geq 0{,}18D_o$

where

D_o = the external diameter of the parallel portion of the end, in mm

3.1.3 For torispherical ends:

the internal radius, $R_i \leq D_o$

the internal knuckle radius, $r_i \geq 0{,}1D_o$

the internal knuckle radius, $r_i \geq 3t$

the external height, $H \geq 0{,}18D_o$, and is determined as follows:

$$H = R_o - [(R_o - 0{,}5D_o)(R_o + 0{,}5D_o - 2r_o)]^{1/2}$$

3.1.4 In addition to the formula in 3.1.1 the thickness, t, of a torispherical head, made from more than one plate, in the crown section is to be not less than that determined by the following formula:

$$t = \frac{pR_i}{20\sigma J - 0{,}5p} + 0{,}75 \quad \text{mm}$$

where

t, p, R_i, σ and J are as defined in 1.2.

3.1.5 The thickness required by 3.1.1 for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the crown section for a distance not less than $0{,}5(R_i\, t)^{1/2}$ mm, before reducing to the crown thickness permitted by 3.1.4

where

t = the required thickness from 3.1.1.

3.1.6 In all cases, H is to be measured from the commencement of curvature, *see* Fig. 9.3.2.

3.1.7 The minimum thickness of the head, t, is not to be less than $3 + \frac{D_i}{1500}$ mm where D_i is as defined in 1.2.

3.1.8 The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

3.1.9 For ends which are butt welded to the drum shell, *see* 1.9, the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 2.1.

3.2 Shape factors for dished ends

3.2.1 The shape factor, K, to be used in 3.1.1, is to be obtained from the curves in Fig. 9.3.1 and depends on the ratio of height to diameter $\frac{H}{D_o}$.

3.2.2 The lowest curve in the series provides the factor, K, for plain (i.e. unpierced) ends. For lower values of $\frac{H}{D_o}$, K depends upon the ratio of thickness to diameter, $\frac{t}{D_o}$, as well as on the ratio $\frac{H}{D_o}$, and a trial calculation may be necessary to arrive at the correct value of K.

3.3 Dished ends with unreinforced openings

3.3.1 Openings in dished ends may be circular, obround or approximately elliptical.

3.3.2 The upper curves in Fig. 9.3.1 provide values of K to be used in 3.1.1, for ends with unreinforced openings. The selection of the correct curve depends on the value $\frac{d}{(D_ot)}^{1/2}$ and a trial calculation is necessary to select the correct curve,

where

d = the diameter of the largest opening in the end plate (in the case of an elliptical opening, the larger axis of the ellipse), in mm

t = minimum thickness, after dishing, in mm

D_o = outside diameter of dished end, in mm.

3.3.3 The following requirements must in any case be satisfied:

$$\frac{t}{D_o} \leq 0{,}10$$

$$\frac{d}{D_o} \leq 0{,}70$$

3.3.4 From Fig. 9.3.1 for any selected ratio of $\frac{H}{D_o}$ the curve for unpierced ends gives a value for $\frac{d^{1/2}}{(D_ot)}$ as well as for K. Openings giving a value of $\frac{d^{1/2}}{(D_ot)}$ not greater than the the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.

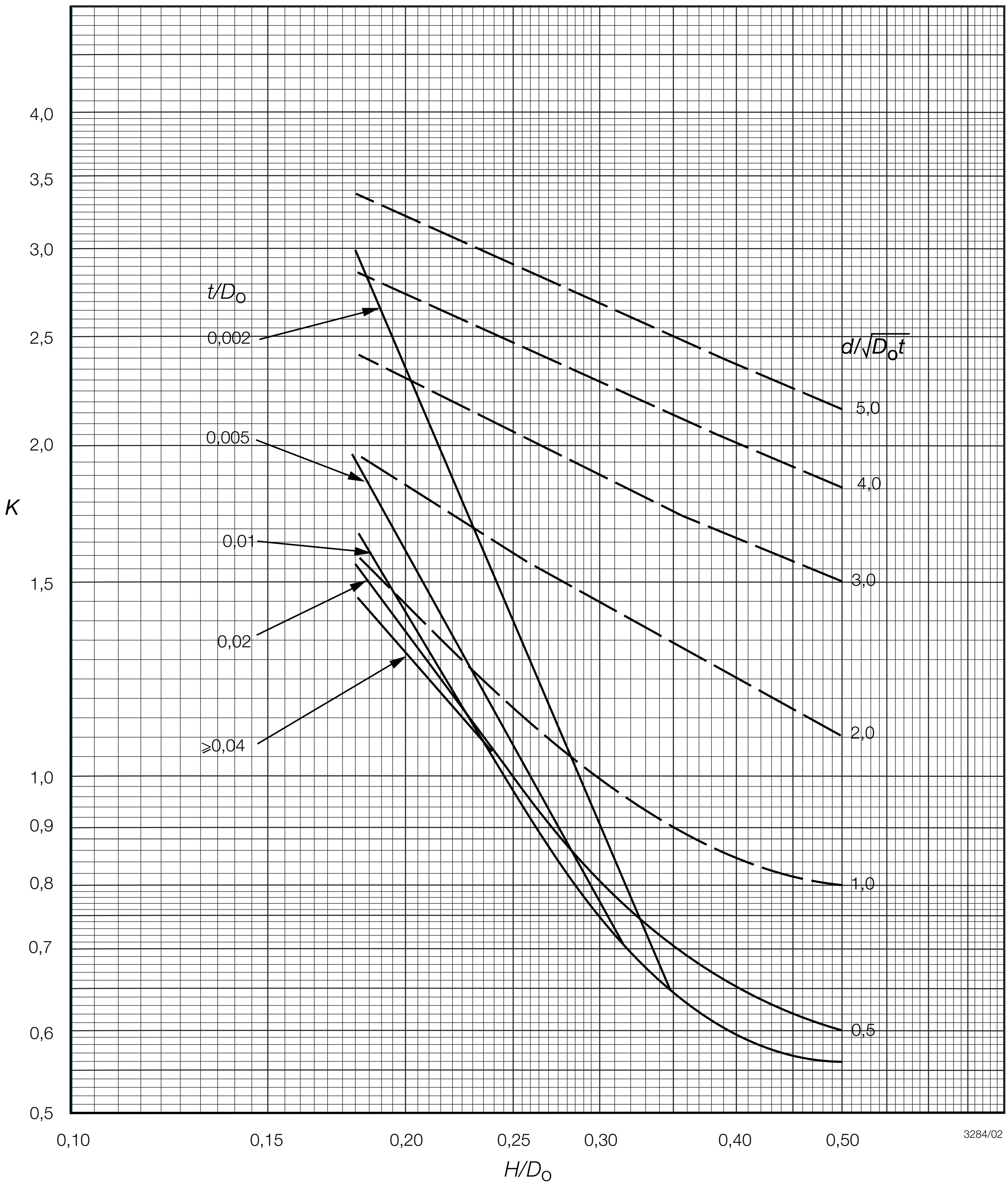


Fig. 9.3.1 Shape factor

3.4 Flanged openings in dished ends

3.4.1 The requirements in 3.3 apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

3.4.2 Where openings are flanged, the radius, r_m, of the flanging is to be not less than 25 mm, *see* Fig. 9.3.2(d). The thickness of the flanged portion may be less than the calculated thickness.

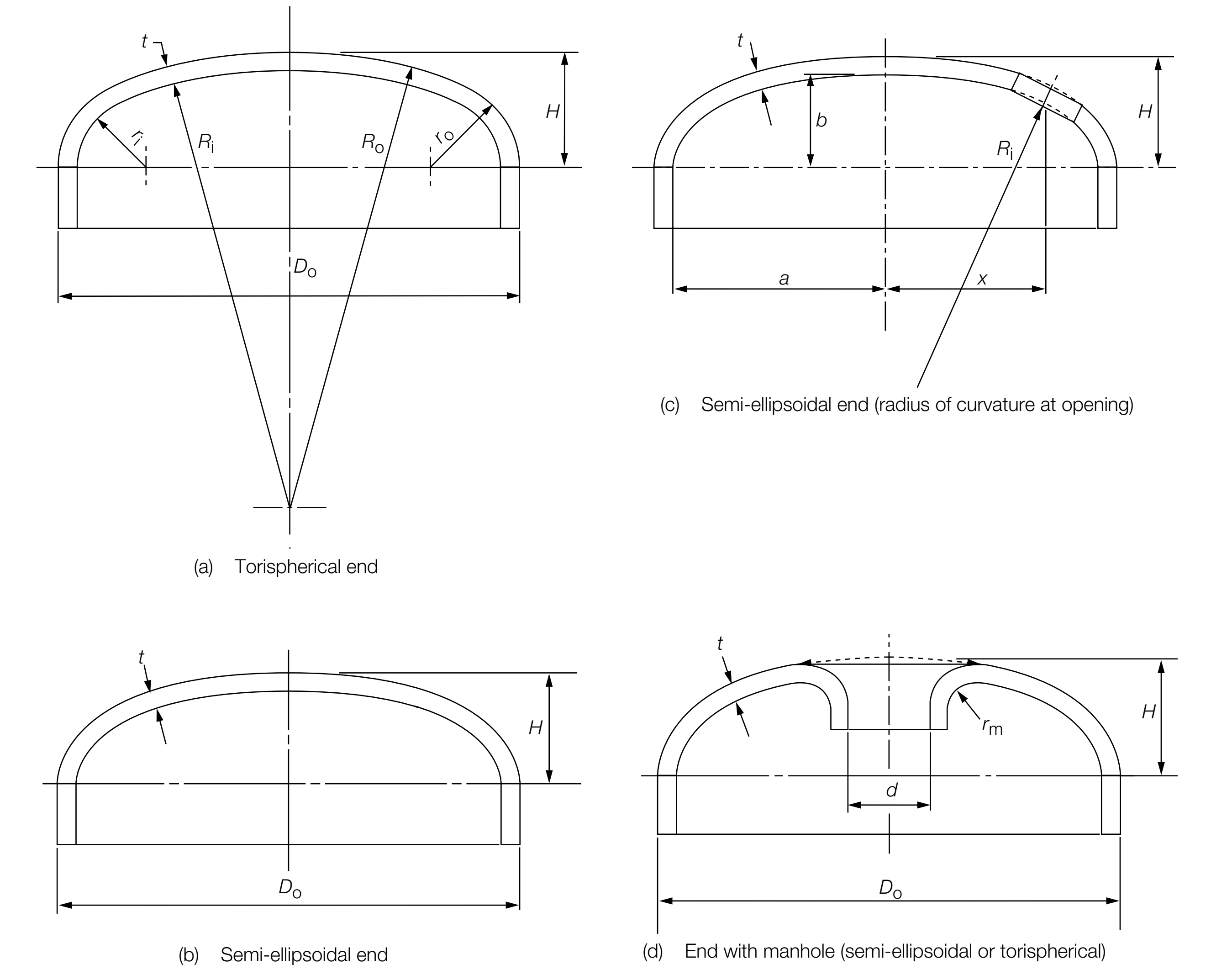


Fig. 9.3.2 Typical dished ends

3.5 Location of unreinforced and flanged openings in dished ends

3.5.1 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in Fig. 9.3.3.

3.6 Dished ends with reinforced openings

3.6.1 Where it is desired to use a large opening in a dished end of less thickness than would be required by 3.3, the end is to be reinforced. This reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods, *see* Fig. 9.3.4. Forged reinforcements may be used.

3.6.2 Reinforcing material within the following limits may be taken as effective reinforcement:

(a) The effective width l_1 of reinforcement is not to exceed $(2R_i)^{1/2}$ t or $0{,}5d_o$, whichever is the lesser.

(b) The effective length l_2 of a reinforcing ring is not to exceed $(d_o\, t_b)^{1/2}$

where

R_i = the internal radius of the spherical part of a torispherical end, in mm, or

R_i = the internal radius of the meridian of the ellipse at the centre of the opening, of a semi-ellipsoidal end, in mm, and is given by the following formula:

$$\frac{[a^4 - x^2\,(a^2 - b^2)]^{3/2}}{a^4\, b}$$

where

a, b and x are shown in Fig. 9.3.2(c)

d_o = external diameter of ring or standpipe, in mm

t_b = actual thickness of ring or standpipe, in mm

l_1 and l_2 are as shown in Fig. 9.3.4.

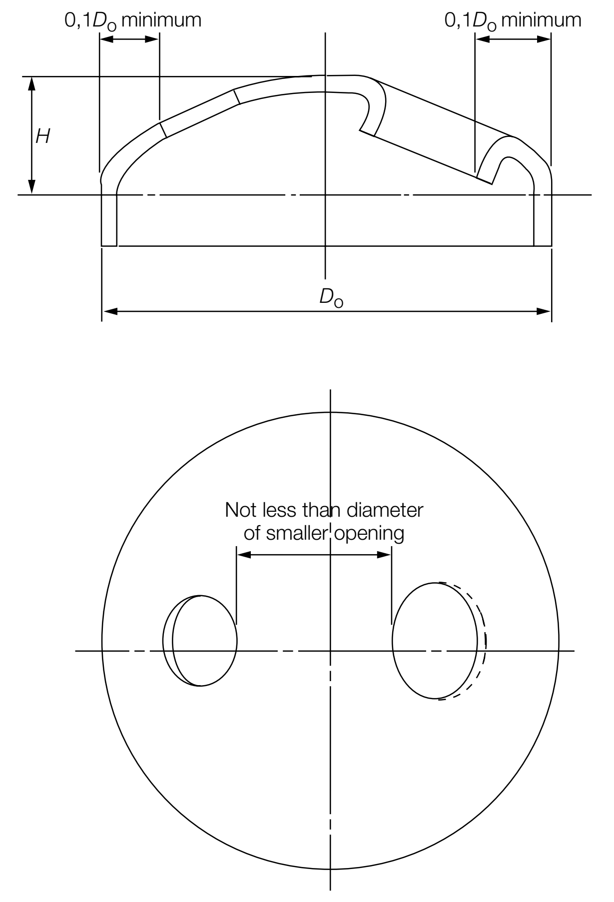


Fig. 9.3.3 Opening in dished ends

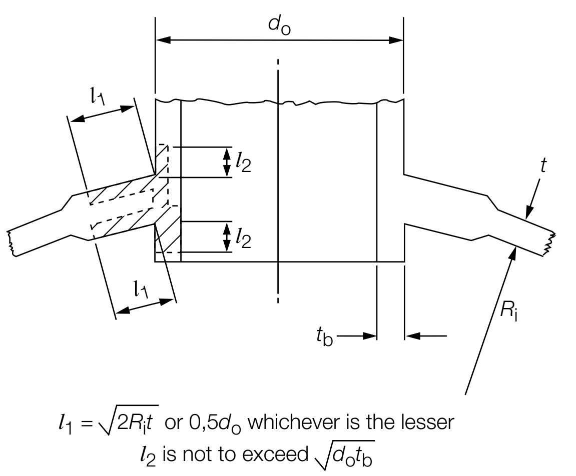


Fig. 9.3.4 Limits of reinforcement

3.6.3 The shape factor, K, for a dished end having a reinforced opening can be read from Fig. 9.3.1 using the value obtained from:

$$\frac{d_o - \frac{A}{t}}{\sqrt{D_o t}} \text{ and } \frac{d}{\sqrt{D_o t}}$$

where

A = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on Fig. 9.3.4.

As in 3.3, a trial calculation is necessary in order to select the correct curve.

3.6.4 The area shown in Fig. 9.3.4 is to be obtained as follows:

- Calculate the cross-sectional area of reinforcement both inside and outside the end plate within the length, l_1
- plus the full cross-sectional area of that part of the ring or standpipe which projects inside the end plate up to the distance l_2
- plus the full cross-sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance l_2, and deduct the sectional area which the ring of standpipe would have if its thickness were as calculated in accordance with 6.1.

3.6.5 If the material of the ring or the reinforcing plates has an allowable stress value lower than that of the end plate, then the effective cross-sectional area, A, is to be multiplied by the ratio:

$$\frac{\text{allowable stress of reinforcing plate at design temperature}}{\text{allowable stress of end plate at design temperature}}$$

3.7 Torispherical dished ends with reinforced openings

3.7.1 If an opening and its reinforcement are positioned entirely within the crown section, the compensation requirements are to be as for a spherical shell, using the crown radius as the spherical shell radius. Otherwise, the requirements of 3.6 are to be applied.

■ *Section 4* Dished ends for Class 3 pressure vessels

4.1 Minimum thickness

4.1.1 As an alternative to the formula in 3.1.1 for Class 3 vessels only, the minimum thickness, t, of a torispherical unstayed end dished from plate and having pressure on the concave or convex side is to be determined by the following formula:

$$t = \frac{p\,R_i}{CS}$$

where

t, p and R_i are as defined in 1.2

C = 2,57 for ends concave to pressure

= 1,65 for ends convex to pressure

S = specified minimum tensile strength of plate, in N/mm^2, which should be not less than 410 N/mm^2.

4.1.2 The inside radius of curvature, R_i, of the end plate is to be not greater than the external diameter of the cylinder to which it is attached.

4.1.3 The inside knuckle radius, r_i, of the arc joining the cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate, and in no case less than 65 mm.

4.1.4 Ends convex to pressure are not to be used for vessels exceeding 610 mm internal diameter.

4.1.5 Where the end is provided with a flanged manhole, the thickness of the end, in mm, determined by 4.1.1, is to be increased by 3 mm, and the total depth, H, of the manhole flange, measured from the outer surface of the plate on the minor axis, is to be not less than:

$$H = \sqrt{t_1 W}$$

where

t_1 = required thickness of the plate, in mm

H = depth of flange, in mm

W = minor axis of the manhole, in mm.

■ *Section 5* Standpipes and branches

5.1 Minimum thickness

5.1.1 The minimum wall thickness, t, of standpipes and branches is to be not less than the greater of the two values determined by the following formulae, making such additions as may be necessary on account of bending, static loads and vibration:

$$t = \frac{pD_o}{20\sigma + p} + 0{,}75 \text{ mm}$$

$$t = 0{,}015D_o + 3{,}2 \text{ mm}$$

where

t, p, D_o and σ are as defined in 1.2.

If the second formula applies, the thickness need only be maintained for a length, L, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3{,}5\sqrt{D_o t} \text{ mm}$$

5.1.2 In no case need the wall thickness exceed the minimum shell thickness as required by 2.1 or 3.1, as applicable.

■ *Section 6* Unstayed circular flat end plates

6.1 Minimum thickness

6.1.1 Ends attached by welding are to be designed such that the minimum thickness of flat plates is to be determined by the following formula:

$$t = d_i \sqrt{\frac{p\,C}{\sigma}} + 0{,}75 \text{ mm}$$

where

p and σ are as defined in 1.2

t = minimum thickness of end plate, in mm

d_i = internal diameter of circular shell, in mm

C = a constant depending on method of end attachment, *see* Fig. 9.6.1.

(a) For end plates welded as shown in Fig. 9.6.1(a):

C = 0,019 for circular shells.

(b) For end plates welded as shown in Figs. 9.6.1(b) and (c)

C = 0,028 circular shells.

6.1.2 Where flat end plates are bolted to flanges attached to the ends of headers, the flanges and end plates are to be in accordance with recognized pipe flange standards.

6.1.3 Openings in flat plates are to be compensated in accordance with Fig. 9.2.1(a) or (b), with the value of A_1, the compensation required, calculated as follows:

$$A_1 = \frac{d_o}{2{,}4}\, t_f \text{ mm}^2$$

where

d_o = diameter of hole in flat plate, in mm

t_f = required thickness of the flat plate in the area under consideration, in mm, calculated in accordance with 6.1.1, as applicable, without corrosion allowance

Limit D = $0{,}5d_o$.

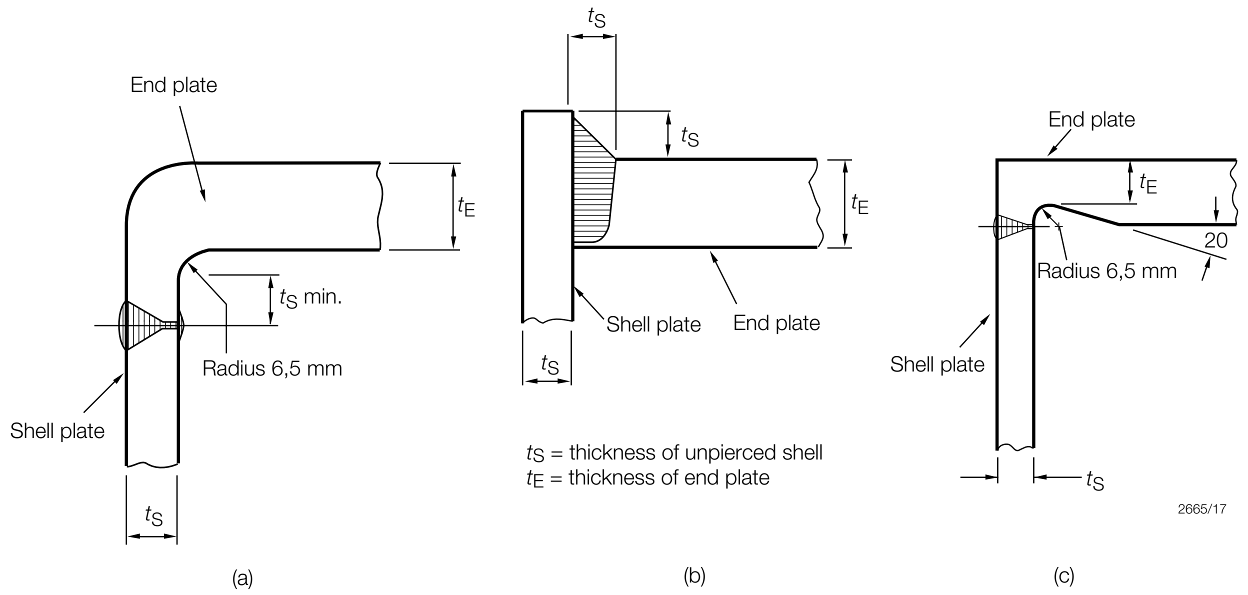


Fig. 9.6.1 Typical methods of attachment of un-stayed circular flat end plates

■ *Section 7* **Construction**

7.1 Access arrangements

7.1.1 Pressure vessels are to be so made that the internal surfaces may be examined. Wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces.

7.1.2 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

7.1.3 Doors for manholes and sightholes are to be formed from steel plate or other approved construction, and all jointing surfaces are to be machined.

7.1.4 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of the opening are not to exceed those of the door by more than 3 mm. The width of the gasket seat is not to be less than 16 mm.

7.1.5 Doors of the internal type for openings not larger than 230 x 180 mm need be fitted with only one stud, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is not to be less than the strength of the stud or bolt.

7.1.6 The crossbars or dogs for doors are to be of steel.

7.1.7 External circular flat cover plates are to be in accordance with a recognized standard.

7.2 Torispherical and semi-ellipsoidal ends

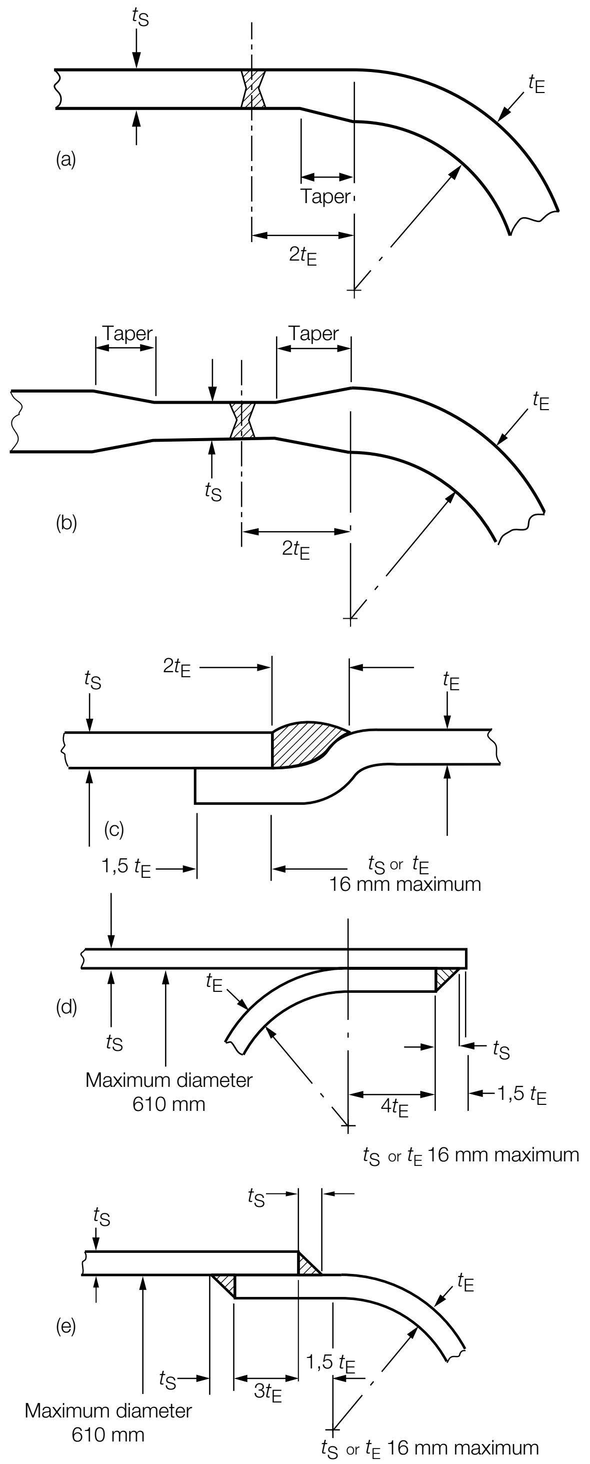
7.2.1 For typical acceptable types of attachment for dished ends to cylindrical shells, *see* Fig. 9.7.1. Types (d) and (e) are to be made a tight fit in the cylindrical shell.

7.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

7.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see* 3.1.

7.3 Welded attachments to pressure vessels

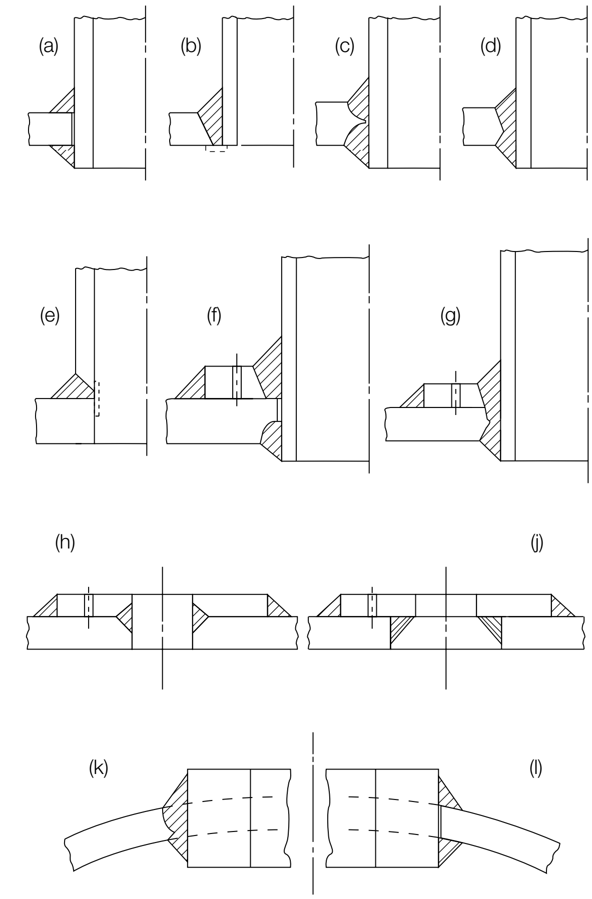
7.3.1 Unless the actual thickness of the shell or end is at least twice that required by calculation for a seamless shell or end, whichever is applicable, doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet, to minimize load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded, and are to be provided with a ‘tell-tale’ hole not greater than 9,5 mm in diameter, open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel, or as a means of indicating any leakage during hydraulic testing and in service, *see* Chapter 14.



Type of end attachment	Acceptable for
(a) and (b)	All classes
(c)	2/1, 2/2 and 3
(d) and (e)	Class 3 only

Fig. 9.7.1
Typical attachments of dished ends to cylindrical shells

7.3.2 For acceptable methods of attaching standpipes, branches, compensating plates and pads, *see* Fig. 9.7.2. Alternative methods of attachment may be accepted provided details are submitted for consideration.



Types (a) and (l) attachments are not to be used for openings which require to be compensated. Backing rings may be used with types (b) and (e)

Fig. 9.7.2
Typical acceptable methods of attaching branches and pads

7.3.3 Where fillet welds are used to attach standpipes or set-in pads, there are to be equal sized welds both inside and outside the vessel, *see* Fig. 9.7.2(a) and (l). The leg length of each of the fillet welds is to be not less than 1,4 times the actual thickness of the thinner of the parts being joined.

7.4 Welded-on flanges, butt welded joints and fabricated branch pieces

7.4.1 Flanges may be cut from plates or may be forged or cast. Hubbed flanges are not to be machined from plate. Flanges are to be attached to branches by welding. Alternative methods of flange attachment will be subject to special consideration.

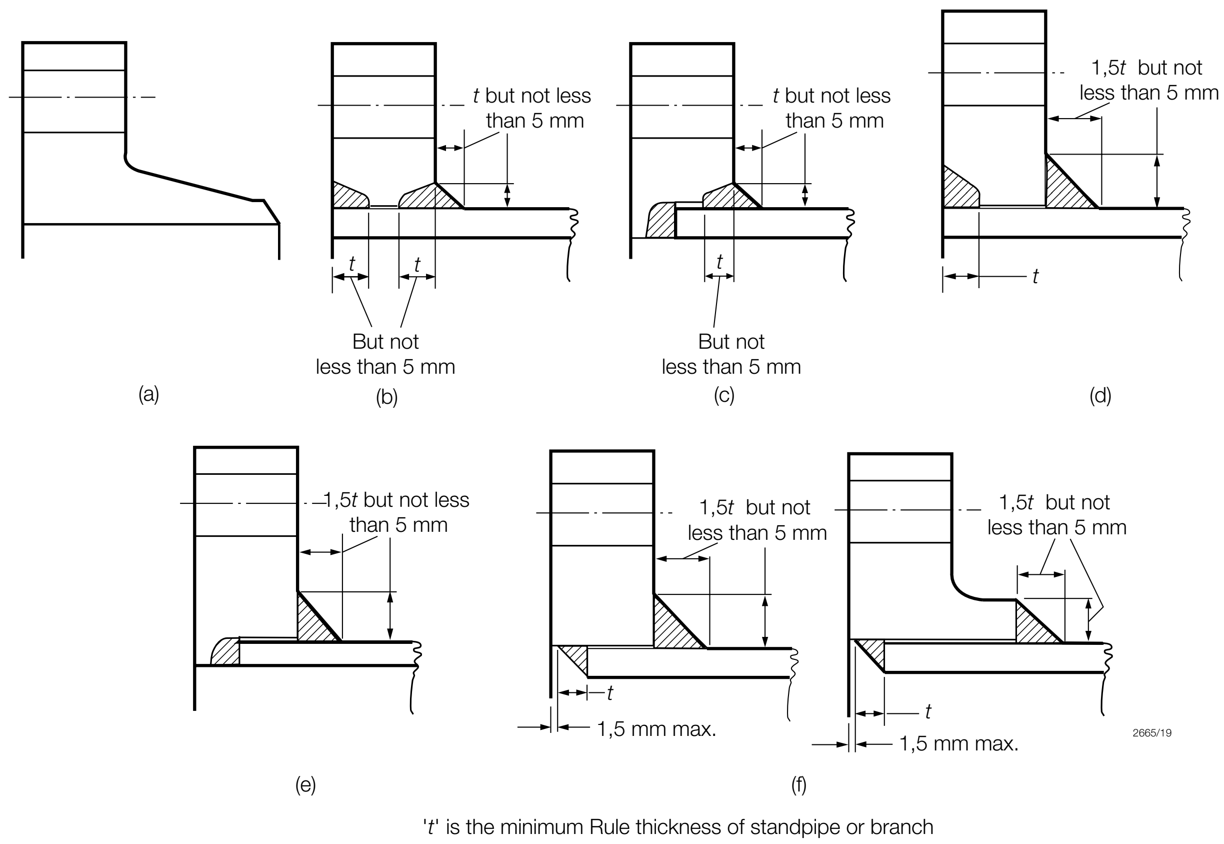


Fig. 9.7.3 Typical examples of welded flange connections

7.4.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the branches are intended.

7.4.3 Flange attachments and pressure-temperature ratings in accordance with materials and design of recognized standards will be accepted.

7.4.4 Typical examples of welded-on flange connections are shown in Fig. 9.7.3(a) to (f). Types (c) and (e), however, are not to be used for pipes having a bore of less than 75 mm.

7.4.5 Welded-on flanges are not to be a tight fit on the branch. The maximum clearance between the bore of the flange and the outside diameter of the branch is to be 3 mm at any point, and the sum of the diametrically opposite clearances is not to exceed 5 mm.

7.4.6 Where butt welds are employed in the attachment of flange type (a), or in the construction of standpipes or branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint.

7.4.7 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to branches exceeding 100 mm diameter or 9,5 mm thick. The welding is to be carried out in accordance with the appropriate paragraphs of Chapter 14.

■ *Section 8*
Mountings and fittings

8.1 General

8.1.1 Each pressure vessel or system is to be fitted with a stop valve situated as close as possible to the shell.

8.1.2 Adequate arrangements are to be provided to prevent over-pressure of any part of a pressure vessel which can be isolated. Pressure gauges are to be fitted in positions where they can be easily read.

8.1.3 Adequate arrangements are to be provided for draining and venting the separate parts of each pressure vessel.

8.2 Receivers containing pressurized gases

8.2.1 Each receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

8.2.2 Each receiver is to be provided with a relief valve.

8.2.3 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C, *see also* 8.2.4 and 8.2.5.

8.2.4 Where a fixed system utilizing fire-extinguishing gas is fitted, to protect a machinery space containing (an) air receiver(s), fitted with a fusible plug, it is recommended that the discharge from the fusible plug be piped to the open deck.

8.2.5 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

■ *Cross-references*

For starting air pipe systems and safety fittings, *see* Ch 2,7.3.

■ *Section 9* Hydraulic tests

9.1 General

9.1.1 Pressure vessels covered by this Chapter are to be tested on completion to a pressure, p_T, determined by the following formula, without showing signs of weakness or defect:

$$p_T = 1{,}3 \frac{\sigma_{50}}{\sigma_T} \frac{t}{(t - 0{,}75)} p$$

but in no case is to exceed

$$p_T = 1{,}5 \frac{t}{(t - 0{,}75)} p$$

where

p = design pressure, in bar
p_T = test pressure, in bar
t = nominal thickness of shell as indicated on the plan, in mm
σ_T = allowable stress at design temperature, in N/mm^2
σ_{50} = allowable stress at 50°C, in N/mm^2.

9.2 Mountings

9.2.1 Mountings are to be subjected to a hydraulic test of twice the approved design pressure.

■ *Section 10* Plate heat exchangers

10.1 General

10.1.1 Plate heat exchangers are to be classed as follows.
Class 2 where either of the following conditions apply:
(a) the maximum metal design temperature is 150°C, or greater, or
(b) design pressure is 17,2 bar, or greater.
Class 3 in all other cases.

10.1.2 Where the design temperature is equal to, or lower than minus 10°C, a higher class is to apply.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to the design and construction of piping systems, including pipe fittings forming parts of such systems, including pipe fittings forming parts of such systems, where the temperature does not exceed 300°C.

1.1.2 For systems having temperatures greater than 300°C, the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) will be applicable.

1.1.3 The materials used for pipes, valves and fittings are to be suitable for the medium and the service for which the piping is intended.

1.2 Design symbols

1.2.1 The symbols used in this Chapter are defined as follows:

a = percentage negative manufacturing tolerance on thickness
c = corrosion allowance, in mm
D = outside diameter of pipe, in mm, *see* 1.2.2
d = inside diameter of pipe, in mm, *see* 1.2.3
e = weld efficiency factor, *see* 1.2.4
p = design pressure, in bar, *see* 1.3
p_t = hydraulic test pressure, in bar
R = radius of curvature of a pipe bend at the centreline of the pipe, in mm
T = design temperature, in °C, *see* 1.4
t = minimum thickness of a straight pipe, in mm, including corrosion allowance and negative tolerance where applicable
t_b = the minimum thickness of a straight pipe, in mm, to be used for a pipe bend including bending allowance corrosion allowance and negative tolerance, where applicable.
σ = maximum permissible design stress, in N/mm^2.

1.2.2 The outside diameter, *D*, is subject to manufacturing tolerances, but these are not to be used in the evaluation of formulae.

1.2.3 The inside diameter, *d*, is not to be confused with nominal pipe size, which is an accepted designation associated with outside diameters of standard rolling sizes.

1.2.4 The weld efficiency factor, *e*, is to be taken as 1 for seamless and electric resistance and induction welded steel pipes. Where other methods of pipe manufacture are proposed, the value of *e* will be specially considered.

1.3 Design pressure

1.3.1 The design pressure, *p*, is the maximum permissible working pressure and is to be not less than the highest set pressure of the safety valve or relief valve.

1.3.2 In boiler installations, the design pressure for steam piping is to be taken as the design pressure of the boiler, i.e. not less than the highest set pressure of any safety valve on the boiler.

1.3.3 The design pressure of feed piping and other piping on the discharge from pumps is to be taken as the pump pressure at full rated speed against a shut valve. Where a safety valve or other protective device is fitted to restrict the pressure to a lower value than the shut valve load, the design pressure is to be the highest set pressure of the device.

1.3.4 For design pressure of steering gear components and piping, *see* Ch 15, 3.1.6.

1.3.5 For design pressure of hydraulic system for liftable wheelhouse systems, *see* Ch 18, 3.1.5.

1.4 Design temperature

1.4.1 The design temperature is to be taken as the maximum temperature of the internal fluid, but in no case is it to be less than 50°C.

1.5 Classes of pipes

1.5.1 Pressure piping systems are divided into three classes for the purpose of assigning appropriate testing requirements, type of joints to be adopted, heat treatment and weld procedure.

1.5.2 Dependent on the service for which they are intended, Class II and III pipes are not to be used for design pressure or temperature conditions in excess of those shown in Table 10.1.1. Where either the maximum design pressure or temperature exceeds that applicable to Class II pipes, Class I pipes are to be used, *see* 1.1.2.

1.5.3 In addition to the pressure piping systems in Table 10.1.1, Class III pipes may be used for open ended piping, e.g. overflows, vents, boiler waste steam pipes, open ended drains, etc.

Table 10.1.1 Maximum pressure and temperature conditions for Class II and III piping systems

Piping system	Class II		Class III	
	p	T	p	T
	bar	°C	bar	°C
Steam	16,0	300	7,0	170
Thermal oil	16,0	300	7,0	150
Flammable Liquids (*see* Note 1)	16,0	150	7,0	60
Other media	40,0	300	16,0	200
Cargo Oil	40,0	300	16,0	200

NOTES
1. Flammable liquids include: oil fuel, lubricating oil and flammable hydraulic oil.
2. For Class limitations of grey cast iron, *see also* 4.2.

1.6 Materials

1.6.1 Materials for ferrous castings and forgings of Class I and Class II piping systems are to be produced at works approved by Lloyd's Register (hereinafter referred to as 'LR') unless otherwise specifically mentioned in the Rules. They are in general, to be tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.6.2 The manufacturer's test certificate for materials for pipes, valves and fittings of Class I and Class II piping systems will be accepted in lieu of LR's materials certificate where the maximum nominal pipe diameter is less than 50 mm or the product of working pressure in bar times nominal diameter in mm is less than 2500.

1.6.3 For copper alloys having a working temperature < 200°C, the manufacturer's test certificate for materials for pipes, valves and fittings of Class I and Class II piping systems will be accepted in lieu of LR's materials certificate where the maximum nominal pipe diameter is less than 50 mm or the product of working pressure in bar times nominal diameter in mm is less than 1500.

1.6.4 The manufacturer's test certificate for materials for ship-side valves and fittings and valves on the collision bulkhead equal to or less than 500 mm nominal diameter will be accepted in lieu of LR's materials certificate where the valves and fittings are in accordance with a recognized National Standard applicable to the intended application and are manufactured and tested in accordance with the appropriate requirements of the Rules for Materials.

■ *Section 2*
Carbon and low alloy steels

2.1 Carbon and low alloy steel pipes, valves and fittings

2.1.1 Materials for Class I and Class II piping systems, also for shipside valves and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the appropriate requirements of the Rules for Materials, *see also* 1.6.

2.1.2 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable national specifications. Pipes having forge butt welded longitudinal seams are not to be used for oil fuel systems, for heating coils in oil tanks, or for pressures exceeding 4,0 bar. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of material.

2.2 Wrought steel pipes and bends

2.2.1 The maximum permissible design stress, σ, is to be taken as the lowest of the following values:

$$\sigma = \frac{E_t}{1,6} \qquad \sigma = \frac{R_{20}}{2,7}$$

where

E_t = specified minimum lower yield or 0,2 per cent proof stress at the design temperature.

R_{20} = specified minimum tensile strength at ambient temperature.

Values of the maximum permissible design stress, σ, may be obtained from the properties of the steels specified in Chapter 6 of the Rules for Materials are shown in Table 10.2.1 for carbon and carbon-manganese steels. For intermediate values of specified minimum tensile strengths and temperatures, values of the permissible design stress may be obtained by interpolation.

2.2.2 Where it is proposed to use alloy steels other than those detailed in Chapter 6 of the Rules for Materials, particulars of the tube sizes, design conditions and appropriate national or proprietary material specifications are to be submitted for consideration.

2.2.3 The minimum thickness, *t*, of straight steel pipes is to be determined by the following formula:

$$t = \left(\frac{p\,D}{20\sigma e + p} + c\right) \frac{100}{100 - a} \text{ mm}$$

where

p, D, e and a are defined in 1.2.1

σ is defined in 2.2.1 and obtained from Table 10.2.1

c is obtained from Table 10.2.2.

2.2.4 For pipes passing through tanks, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with Table 10.2.2.

Table 10.2.1 Carbon and carbon-manganese steel pipes

Specified minimum tensile strength, in N/mm^2	Maximum permissible stress, in N/mm^2					
	Maximum design temperature, in °C					
	50	100	150	200	250	300
320	107	105	99	92	78	62
360	120	117	110	103	91	76
410	136	131	124	117	106	93
460	151	146	139	132	122	111
490	160	156	148	141	131	121

Table 10.2.2 Values of *c* for steel pipes

Piping service	*c* mm
Saturated steam systems	0,8
Steam coil systems in cargo tanks	2,0
Feed water for boilers in open circuit systems	1,5
Feed water for boilers in closed circuit systems	0,5
Blow down (for boilers) systems	1,5
Compressed air systems	1,0
Hydraulic oil systems	0,3
Lubricating oil systems	0,3
Fuel oil systems	1,0
Cargo oil systems	2,0
Refrigerating plants	0,3
Fresh water systems	0,8
Water systems in general (ballast & cooling water)	3,0
Cargo pipes of ships carrying liquefied natural or petroleum gases	0,3

2.2.5 Where the pipes are efficiently protected against corrosion, the corrosion allowance may be reduced by not more than 50 per cent.

2.2.6 Pipes are not to pass through void spaces which are permanently sealed as mentioned in Ch 11, 3.1.4.

2.2.7 The minimum thickness, t_b, of a straight steel pipe to be used for a pipe bend is to be determined by the following formula, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{p\,D}{20\sigma e + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right]\frac{100}{100 - a} \quad \text{mm}$$

where

p, D, R, e, b and a are as defined in 1.2.1

σ is defined in 2.2.1, and c is to be obtained from Table 10.2.2

In general, R is to be not less than $3D$.

Table 10.2.3 Minimum thickness for steel pipes

External diameter, *D*, mm	Minimum pipe thickness, mm	Air and sounding pipes for structural tanks, mm
10,2 – 12	1,6	—
13,5 – 19	1,8	—
20 – 44,5	2,0	4,5
48,3 – 63,5	2,3	4,5
70 – 82,5	2,6	4,5
88,9 – 108	2,9	4,5
114,3 – 127	3,2	4,5
133 – 139,7	3,6	4,5
152,4 – 168,3	4,0	4,5
177,8	4,5	5,0
193,7	4,5	5,4
219,1	4,5	5,9
244,5 – 273	5,0	6,3
298,5 – 368	5,0	6,3
406,4 – 457,2	6,3	6,3

NOTES
1. The thickness of bilge, ballast and general outboard water systems is to be not less than 4,0 mm.
2. The thickness of bilge, air, overflow and sounding pipes through ballast and oil fuel tanks, ballast lines through oil fuel tanks and oil fuel lines through ballast tanks is to be not less than 6,3 mm.
3. For air bilge, ballast, oil fuel, overflow, sounding, and venting pipes as mentioned in Notes 1 to 2, where the pipes are efficiently protected against corrosion, the thickness may be reduced by not more than 1 mm.
4. For air and sounding pipes, the minimum thickness applies to the part of the pipe outside the tank but not exposed to the weather. The section of pipe exposed to the weather is required to be suitably increased in thickness or in compliance with the requirements of the relevant Authorities.
5. Sounding pipes for cargo tanks, having a flash point of less than 55°C, the minimum thickness is also applicable for the part inside the tank.

2.2.8 Where the minimum thickness calculated by 2.2.4 or 2.2.5 is less than that shown in Table 10.2.3, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used. No allowance is required for negative tolerance, or reduction in thickness due to bending on this nominal thickness. For larger diameters, the minimum thickness will be specially considered. For threaded pipes, where permitted, the minimum thickness is to be measured at the bottom of the thread.

2.3 Pipe joints – General

2.3.1 Joints in pressure pipelines may be made by:

- Welded-on bolted flanges, *see* 2.5.
- Butt welds between pipes or between pipes and valve chests or other fittings, *see* 2.5.
- Loose Flanges, *see* 2.6.
- Socket weld joints, *see* 2.7.
- Welded sleeve joints, *see* 2.8.
- Threaded sleeve joints, *see* 2.9.
- Screwed fittings, *see* 2.10.
- Other mechanical couplings, *see* 2.11.
- Special types of approved joints that have been shown to be suitable for the design conditions. Details are to be submitted for consideration.

2.3.2 The dimensions and materials of flanges, gaskets and bolting, and the press-temperature rating of bolted flanges in pressure pipelines are to be in accordance with recognised national or other established standards.

2.3.3 With the welded pressure piping system referred to in 2.3.1 it is desirable that a few flanged joints be provided at suitable positions to facilitate installation, cold 'pull up' and inspection at Periodical Surveys.

2.3.4 Piping with joints is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

2.3.5 Consideration will be given to accepting joints in accordance with a recognized National or International Standard which is applicable to the intended service and media conveyed.

2.3.6 Where welded pipes are protected against corrosion then the corrosion protection is to be applied after welding or the corrosion protection is to be made good in way of the weld damaged area.

2.3.7 Where it is not possible to make good the corrosion protection of the weld damaged area, the pipe is to be considered to have no corrosion protection.

2.4 Steel pipe flanges

2.4.1 Flanges may be cut from plates or may be forged or cast. The material is to be suitable for the design temperature.

2.4.2 Flange attachments to pipes and pressure-temperature ratings in accordance with National or other approved Standards will be accepted.

2.5 Welded-on flanges, butt welded joints and fabricated branch pieces

2.5.1 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the pipes are intended.

2.5.2 Typical examples of welded-on flange attachments are shown in Fig. 10.2.1(a) to (f). Types (c) and (e), however, are not to be used for pipes having a bore of less than 75 mm.

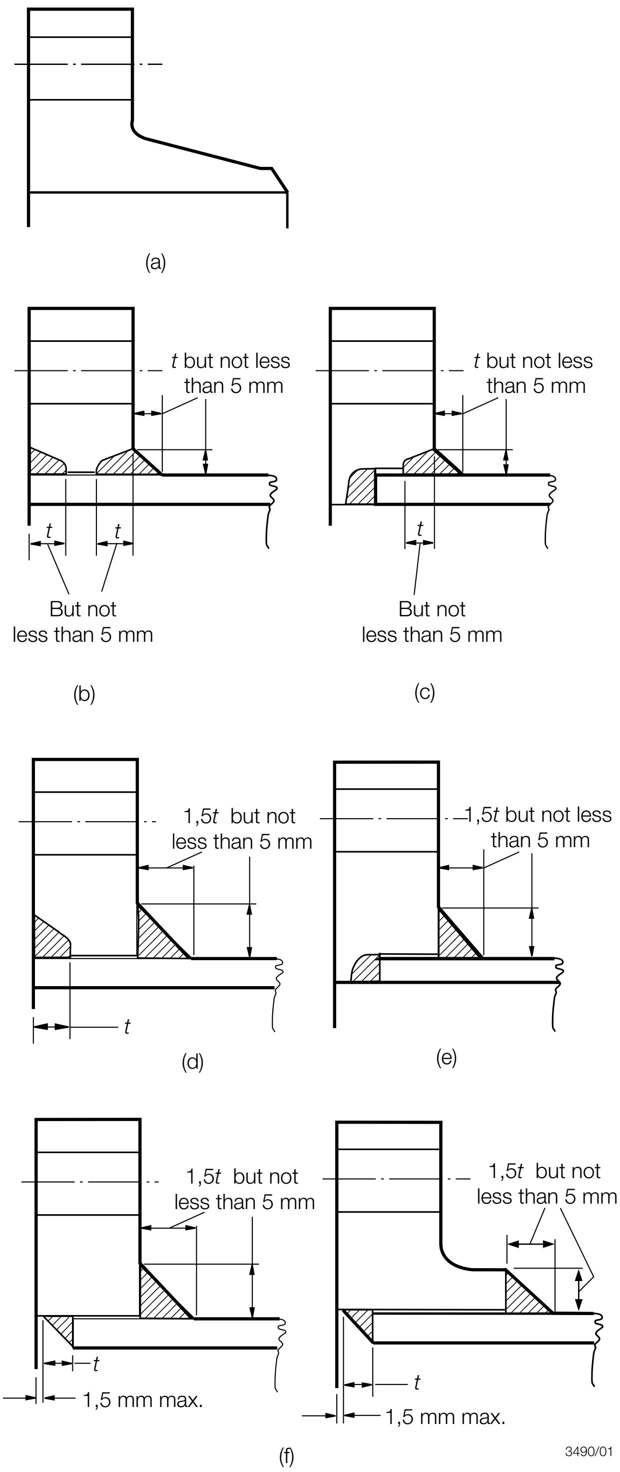


Fig. 10.2.1 Typical welded-on flanges

2.5.3 Butt welded joints are to meet the requirements of Chapter 14.

2.5.4 Welded-on flanges are not to be a tight fit on the pipes. The maximum clearance between the bore of the flange and the outside diameter of the pipe is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

2.5.5 Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided that the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to the thickness of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

2.5.6 Where backing rings are used with flange type (a), they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same materials as the pipes or of mild steel having a sulphur content not greater than 0,05 per cent.

2.5.7 Branches may be attached to pressure pipes by means of welding provided that the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or, alternatively, that the thicknesses of pipe and branch are increased to maintain the strength of the pipe. These requirements also apply to fabricated branch pieces.

2.5.8 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to pipes exceeding 100 mm diameter or 9,5 mm thick. The welding is to be carried out in accordance with the appropriate paragraphs of Chapter 14.

2.6 Loose flanges

2.6.1 Loose flange designs as shown in Fig. 10.2.2 may be used, provided they are in accordance with a recognized National or International Standard.

2.6.2 Loose flange designs where the pipe end is flared as shown in Fig 10.2.2(b) are only to be used for water pipes and on open ended lines.

2.7 Socket weld joints

2.7.1 Socket weld joints may be used in Class III systems with carbon steel pipes of any outside diameter. Socket weld fittings are to be of forged steel and the material is to be compatible with the associated piping. In particular cases, socket welded joints may be permitted for piping systems of Class I and II, having outside diameter not exceeding 88,9 mm. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where toxic media are conveyed.

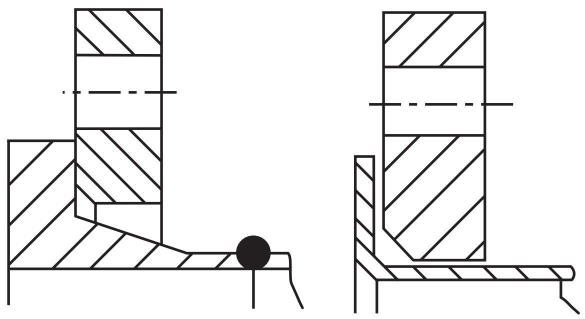


Fig. 10.2.2 Loose flange arrangements

2.7.2 The thickness of the socket weld fittings is to meet the requirements of 2.2.4 but is to be not less than 1,25 times the nominal thickness of the pipe or tube. The diametral clearance between the outside diameter of the pipe and the bore of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the bottom of the socket. *See also* Ch 14, 6.2.3.

2.7.3 The leg lengths of the fillet weld connecting the pipe to the socket weld fitting are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

2.8 Welded sleeve joints

2.8.1 Welded sleeve joints may be used in Class III systems with carbon steel pipes of any outside diameter. In particular cases, welded sleeve joints may be permitted for piping systems of Class I and II, having outside diameter not exceeding 88,9 mm. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where toxic media are conveyed.

2.8.2 Sleeve joints are not to be used in the following locations:

- Bilge pipes in way of deep tanks.
- Air and sounding pipes passing through cargo tanks.

2.8.3 Welded sleeve joints may be used in piping systems for the storage, distribution and utilisation of oil fuel, lubricating or flammable oil systems in machinery spaces provided they are located in readily visible and accessible positions. *See also* Ch 12, 2.6.2.

2.8.4 The thickness of the sleeve is to satisfy the requirements of 2.2.4 and Table 10.2.3 but is to be not less than the nominal thickness of the pipe. The radial clearance between the outside diameter of the pipe and the internal diameter of the sleeve is not to exceed 1 mm for pipes up to a nominal diameter of 50 mm, 2 mm on diameters up to 200 mm nominal size and 3 mm for larger size pipes. The pipe ends are to be separated by a clearance of approximately 2 mm at the centre of the sleeve.

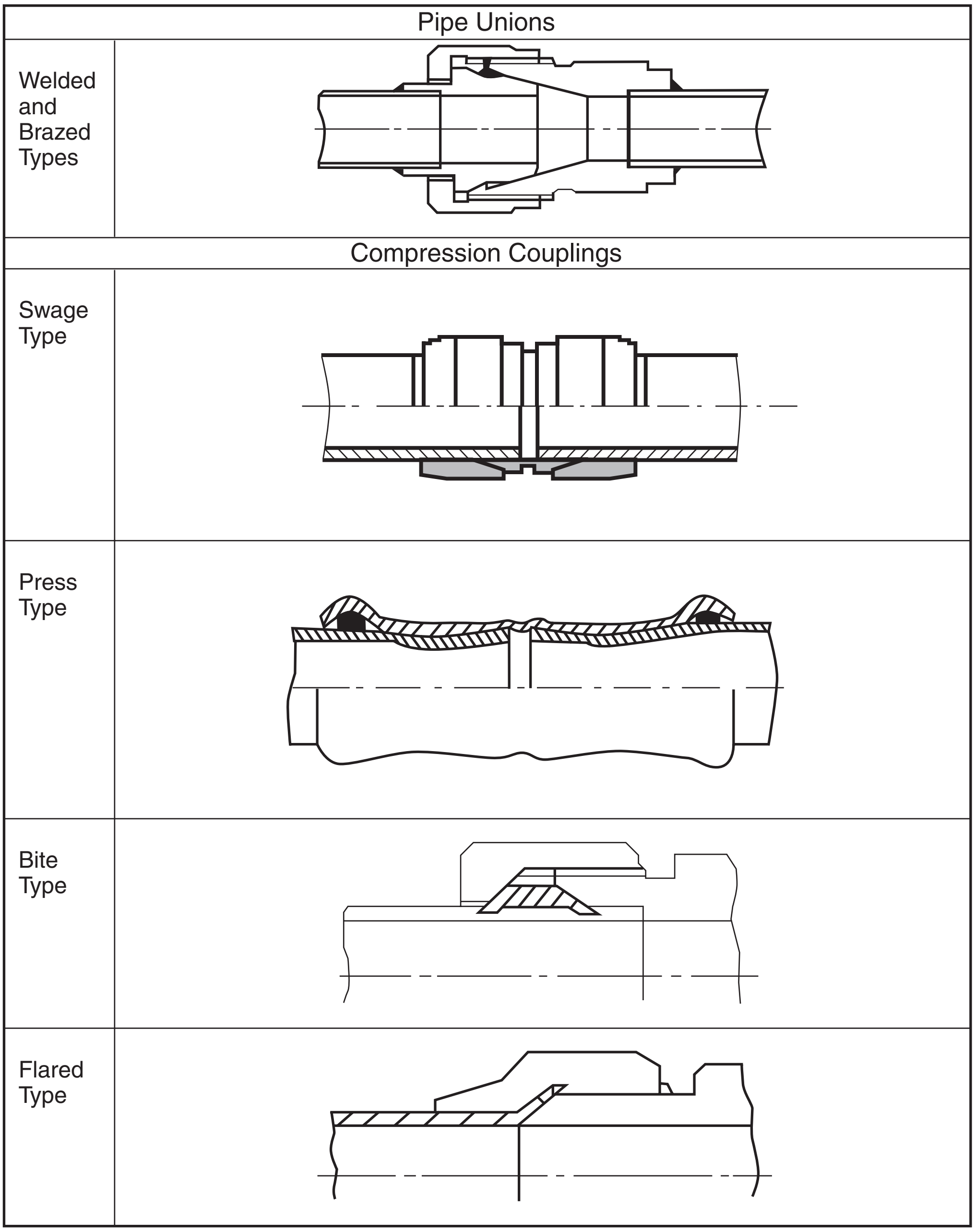


Fig. 10.2.3 Examples of mechanical joints (*see continuation*)

2.8.5 The sleeve material is to be compatible with the associated piping and the leg lengths of the fillet weld connecting the pipe to the sleeve are to be such that the throat dimension of the weld is not less than 0,7 times the nominal thickness of the pipe or tube.

2.8.6 The minimum length of the sleeve is to conform to the following formula:

$L_{si} = 0{,}14D + 36$ mm

where

L_{si} is the length of the sleeve
D is defined in 1.2.1.

2.9 Threaded sleeve joints

2.9.1 Threaded sleeve joints, in accordance with national or other established standards, may be used with carbon steel pipes within the limits given in Table 10.2.4. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where flammable or toxic media is conveyed.

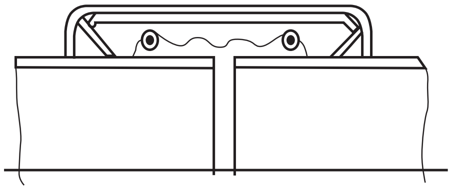
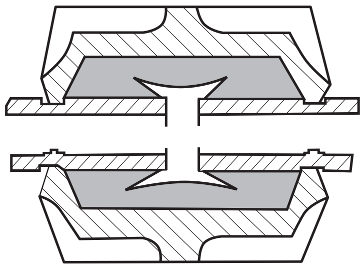
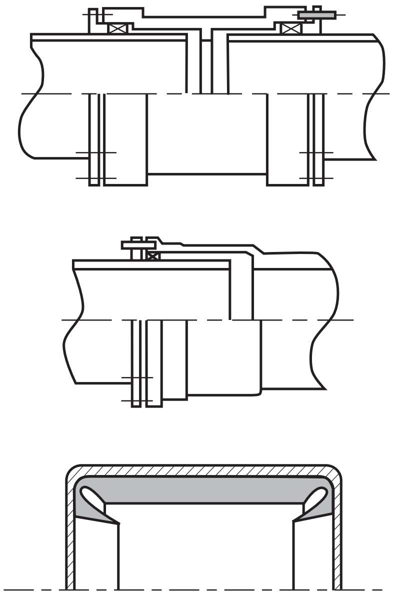
Slip-on Joints	
Grip Type	
Machine Grooved Type	
SlipType	

Fig. 10.2.3 Examples of mechanical joints (*conclusion*)

Table 10.2.4 Limiting design conditions for threaded sleeve joints

Thread type	Outside pipe diameter, in mm		
	Class I	Class II	Class III
Tapered thread	<33,7	<60,3	<60,3
Parallel thread	–	–	<60,3

2.10 Screwed fittings

2.10.1 Screwed fittings, including compression fittings, of an approved type may be used in piping systems for pipes not exceeding 51 mm outside diameter. Where the fittings are not in accordance with an acceptable standard then LR may require the fittings to be subjected to special tests to demonstrate their suitability for the intended service and working conditions.

2.11 Other mechanical couplings

2.11.1 Pipe unions, compression couplings, or slip-on joints, as shown in Fig. 10.2.3, may be used if Type Approved for the service conditions and the intended application. The Type Approval is to be based on the results of testing of the actual joints. The acceptable use for each service is indicated in Table 10.2.5 and dependence upon the Class of piping, with limiting pipe dimensions, is indicated in Table 10.2.6.

2.11.2 Where the application of mechanical joints results in a reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

2.11.3 Construction of mechanical joints is to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects occurring during operation on board.

2.11.4 Materials of mechanical joints are to be compatible with the piping material and internal and external media.

2.11.5 Mechanical joints for pressure pipes are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar, the required burst pressure will be specially considered.

2.11.6 In general, mechanical joints are to be of fire resistant type where required by Table 10.2.5.

2.11.7 Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the sea openings or tanks containing flammable fluids.

2.11.8 The mechanical joints are to be designed to withstand internal and external pressure as applicable and, where used in suction lines, are to be capable of operating under vacuum.

2.11.9 Generally, slip-on joints are not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible. Application of these joints inside tanks may only be accepted where the medium conveyed is the same as that in the tanks.

2.11.10 Unrestrained slip-on joints are only to be used in cases where compensation of lateral pipe deformation is necessary. Usage of these joints as the main means of pipe connection is not permitted.

2.11.11 Restrained slip-on joints are permitted in steam pipes on the weather decks of oil and chemical tankers to accommodate axial pipe movement, *see* Ch 11, 2.7.

2.12 Non-destructive testing

2.12.1 For details of non-destructive tests on piping systems, other than hydraulic tests, *see* Chapter 14.

Table 10.2.5 Application of mechanical joints

Systems	Kind of connections		
	Pipe unions	Compression couplings (6)	Slip-on joints
Flammable fluids (Flash point <55°)			
Cargo oil lines	+	+	+5
Crude oil washing lines	+	+	+5
Vent lines	+	+	+3
Inert gas			
Water seal effluent lines	+	+	+
Scrubber effluent lines	+	+	+
Main lines	+	+	+2,5
Distribution lines	+	+	+5
Flammable fluids (Flash point > 55°)			
Cargo oil lines	+	+	+5
Fuel oil lines	+	+	+2,3
Lubricating oil lines	+	+	+2,3
Hydraulic oil	+	+	+2,3
Thermal oil	+	+	+2,3
Sea-water			
Bilge lines	+	+	+1
Fire main and water spray	+	+	+3
Foam system	+	+	+3
Sprinkler system	+	+	+3
Ballast system	+	+	+1
Cooling water system	+	+	+1
Tank cleaning services	+	+	+
Non-essential systems	+	+	+
Fresh water			
Cooling water system	+	+	+1
Condensate return	+	+	+1
Non-essential system	+	+	+
Sanitary/Drains/Scuppers			
Deck drains (internal)	+	+	+4
Sanitary drains	+	+	+
Scuppers and discharge (overboard)	+	+	—
Sounding/vent			
Water tanks/Dry spaces	+	+	+
Oil tanks (f.p.> 55°C)	+	+	+2,3
Miscellaneous			
Starting/Control air (1)	+	+	—
Service air (non-essential)	+	+	+
Brine	+	+	+
CO_2 system	+	+	—
Steam	+	+	–7

KEY
+ Application is allowed
— Application is not allowed

NOTES
1. Inside machinery spaces of Category A-only approved fire resistant types.
2. Not inside machinery spaces of Category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.
3. Approved fire resistant types.
4. Above freeboard deck only.
5. In pump rooms and open decks - only approved fire resistant types.
6. If compression couplings include any components which are sensitive to heat, they are to be of approved fire resistant type as required for slip-on joints.
7. *See* 2.11.11.
8. A Category A machinery space is a machinery space containing internal combustion machinery for main propulsion or, internal combustion machinery used for purposes other than main propulsion where such machinery has a total power of not less than 375 kW or, containing any oil-fired boiler or oil fuel unit, or any other oil-fired equipment other than boilers.

Table 10.2.6 Application of mechanical joints depending on class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe unions			
Welded and brazed type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Compression couplings			
Swage type	–	–	+
Bite type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Flared type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Press type	–	–	+
Slip-on joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+

KEY
+ Application is allowed
– Application is not allowed

■ *Section 3* Copper and copper alloys

3.1 Copper and copper alloy pipes, valves and fittings

3.1.1 Materials for Class I and Class II piping systems, also for ship-side valves and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the requirements of Chapter 9 of the Rules for Materials. *See also* 1.6.

3.1.2 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable National Specifications. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of material.

3.1.3 Pipes are to be seamless, and branches are to be provided by cast or stamped fittings, pipe pressings or other approved fabrications.

3.1.4 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried. All brazing and welding are to be carried out to the satisfaction of the Surveyor.

3.1.5 Where silver brazing is used, strength is to be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet brace at the back of the flange or at the face is undesirable. The alloy used for silver brazing is to contain not less than 49 per cent silver.

3.1.6 The use of copper-zinc brazing alloy is not permitted.

3.1.7 In general, the maximum permissible service temperature of copper and copper alloy pipes, valves and fittings is not to exceed 200°C for copper and aluminium brass, and 300°C for copper-nickel. Cast bronze valves and fittings complying with the requirements of Chapter 9 of the Rules for Materials may be accepted up to 260°C.

3.1.8 The minimum thickness, t, of straight copper and copper alloy pipes is to be determined by the following formula:

$$t_b = \left(\frac{pD}{20\,\sigma + p} + \mathrm{c}\right)\frac{100}{100 - a} \quad \text{mm}$$

where

p, D and a are as defined in 1.2.1
σ = maximum permissible design stress, in N/mm^2, from Table 10.3.1. Intermediate values of stresses may be obtained by linear interpolation
c = corrosion allowance
= 0,8 mm for copper, aluminium brass, and copper-nickel alloys where the nickel content is less than 10 per cent
= 0,5 mm for copper-nickel alloys where the nickel content is 10 per cent or greater
= 0 where the media is non-corrosive relative to the pipe material.

3.1.9 The minimum thickness, t_b, of a straight seamless copper or copper alloy pipe to be used for a pipe bend is to be determined by the formula below, except where it can be demonstrated that the use of a thickness less than t_b, would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{p\,D}{20\sigma + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right]\frac{100}{100 - a} \quad \text{mm}$$

where

p, D, R, b and a are as defined in 1.2.1
σ and c are as defined in 3.1.7

In general, R is to be not less than $3D$.

Table 10.3.1 Copper and copper alloy pipes

Pipe material	Condition of supply	Specified minimum tensile strength, N/mm^2	Permissible stress, N/mm^2										
			Maximum design temperature, °C										
			50	75	100	125	150	175	200	225	250	275	300
Copper	Annealed	220	41,2	41,2	40,2	40,2	34,3	27,5	18,6	–	–	–	–
Aluminium brass	Annealed	320	78,5	78,5	78,5	78,5	78,5	51,0	24,5	–	–	–	–
90/10 Copper-nickel-iron	Annealed	270	68,6	68,6	67,7	65,7	63,7	61,8	58,8	55,9	52,0	48,1	44,1
70/30 Copper-nickel	Annealed	360	81,4	79,4	77,5	75,5	73,5	71,6	69,6	67,7	65,7	63,7	61,8

3.1.10 Where the minimum thickness calculated by 3.1.7 or 3.1.8 is less than shown in Table 10.3.2, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used. No allowance is required for negative tolerance or reduction in thickness due to bending on this nominal thickness.

Table 10.3.2 Minimum thickness for copper and copper alloy pipes

Standard pipe sizes (outside diameter), in mm	Minimum overriding nominal thickness, in mm	
	Copper	Copper alloy
8 to 10	1,0	0,8
12 to 20	1,2	1,0
25 to 44,5	1,5	1,2
50 to 76,1	2,0	1,5
88,9 to 108	2,5	2,0
133 to 159	3,0	2,5
193,7 to 267	3,5	3,0
273 to 457,2	4,0	3,5
508 and over	4,5	4,0

3.2 Heat treatment

3.2.1 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of fabrication and prior to being tested by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

■ *Section 4* Cast iron

4.1 Spheroidal or nodular graphite cast iron

4.1.1 Spheroidal or nodular graphite iron may be accepted for bilge, ballast and cargo oil piping.

4.1.2 Spheroidal or nodular graphite iron castings for pipes, valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12 per cent on a gauge length of 5,65 $\sqrt{S_o}$, where S_o is the actual cross-sectional area of the test piece.

4.1.3 Castings for Class II and Class III systems are to be manufactured and tested in accordance with the requirements of acceptable National Specifications. *See also* 1.6.

4.1.4 Where the elongation is less than the minimum required by 4.1.2, the material is, in general, to be subject to the same limitations as grey cast iron.

4.2 Grey cast iron

4.2.1 Grey case iron pipes, valves and fittings will, in general, be accepted in Class III piping systems except as stated in 4.2.4.

4.2.2 Grey cast iron valves and fittings may be accepted in Class II steam systems, provided that the design pressure and temperature do not exceed 13 bar and 220°C, respectively.

4.2.3 Grey cast iron is not to be used for the following:

- Pipes for steam systems and pipes, valves and fittings for fire-extinguishing systems.
- Pipes, valves and fittings for boiler blow-down systems.
- Ship-side valves and fittings, *see* Ch 11,2.5.
- Valves fitted on the collision bulkhead, *see* Ch 11,3.5.
- Bilge lines in tanks.
- Pipes and fittings in flammable oil and thermal oil systems where the design pressure exceeds 10 bar or the design operating temperature is greater than 80°C.
- Valves fitted to tanks containing flammable oil under static pressure.
- Piping subject to pressure shock, excessive strains or vibrations.
- Valves chests and fittings for starting air systems, *see* Ch 2,7.4.3.

4.2.4 Grey iron castings for Class III systems are to be manufactured and tested in accordance with acceptable National Specifications.

Section 5
Plastics pipes

5.1 General

5.1.1 Proposals to use plastics pipes in shipboard piping systems will be considered in relation to the properties of the materials, the operating conditions, the intended service and location. Details are to be submitted for approval. Special consideration will be given to any proposed service for plastics pipes not mentioned in these Rules.

5.1.2 Attention is also to be given to the *Guidelines for the Application of Plastic Pipes on Ships* contained in IMO Resolution A.753(18).

5.1.3 Plastics pipes and fittings will, in general, be accepted in Class III piping systems. Proposals for the use of plastics in Class I and Class II piping systems will be specially considered.

5.1.4 For Class I, Class II and any Class III piping systems for which there are Rule requirements, the pipes are to be of a type which has been approved by LR.

5.1.5 For domestic and similar services where there are no Rule requirements, the pipes need not be of a type which has been approved by LR. However, the fire safety aspects as referenced in 5.4, are to be considered.

5.1.6 The use of plastics pipes may be restricted by statutory requirements of the National Authority of the country in which the ship is to be registered.

5.2 Design and performance criteria

5.2.1 Pipes and fittings are to be of robust construction and are to comply with a National or other established Standard, consistent with the intended use. Particulars of pipes, fittings and joints are to be submitted for consideration.

5.2.2 The design and performance criteria of all piping systems, independent of service or location, are to meet the requirements of 5.3.

5.2.3 Depending on the service and location, the fire safety aspects such as fire endurance, flame spread, smoke generation, toxicity and fire protection coatings are to meet the requirements of 5.4.

5.2.4 Plastics piping is to be electrically conductive when:
(a) Carrying fluids capable of generating electrostatic charges.
(b) Passing through dangerous zones and spaces, regardless of the fluid being conveyed.

Suitable precautions against the build up of electrostatic charges are to be provided in accordance with the requirements of 5.5. *See also* Pt 6, Ch 2,1.7.

5.3 Design strength

5.3.1 The strength of pipes is to be determined by hydrostatic pressure tests to failure on representative sizes of pipe. The strength of fittings is to be not less than the strength of the pipes.

5.3.2 The nominal internal pressure, pN_i, of the pipe is to be determined by the lesser of the following:

$$pN_i \leq \frac{p_{st}}{4}$$

$$pN_i \leq \frac{p_{lt}}{2,5}$$

where

p_{st} = short term hydrostatic test failure pressure, in bar
p_{lt} = long term hydrostatic test failure pressure (100 000 hours), in bar

Testing may be carried out over a reduced period of time using suitable standards such as ASTM D2837 and D1598.

5.3.3 The nominal external pressure, pN_e, of the pipe, defined as the maximum total of internal vacuum and external static pressure head to which the pipe may be subjected, is to be determined by the following:

$$pN_e \leq \frac{p_{col}}{3}$$

where

p_{col} = pipe collapse pressure, in bar.

The pipe collapse pressure is not to be less than 3 bar.

5.3.4 Piping is to meet these design requirements over the range of service temperatures it will experience.

5.3.5 High temperature limits and pressure reductions relative to nominal pressures are to be according to a recognized standard, but in each case the maximum working temperature is to be at least 20°C lower than the minimum temperature of deflection under load of the resin or plastics material without reinforcement. The minimum heat distortion temperature is not to be less than 80°C. *See also* Ch 14,4 of the Rules for Materials.

5.3.6 Where it is proposed to use plastics piping in low temperature services, design strength testing is to be made at a temperature 10°C lower than the minimum working temperature.

5.3.7 For guidance, typical temperature and pressure limits are indicated in Table 10.5.1 and Table 10.5.2. The Tables are related to water service only. Transport of chemicals or other media are to be considered on a case by case basis.

5.3.8 The selection of plastics materials for piping is to take account of other factors such as impact resistance, ageing, fatigue, erosion resistance, fluid absorption and material compatibility such that the design strength of the piping is not reduced below that required by these Rules.

5.3.9 Design strength values may be verified experimentally or by a combination of testing and calculation methods.

Table 10.5.1 Typical temperature and pressure limits for thermoplastic pipes

Material	Nominal pressure, bar	Maximum permissible working pressure, bar						
		–20 to 0°C	30°C	40°C	50°C	60°C	70°C	80°C
PVC	10		7,5	6				
	16		12	9	6			
ABS	10	7,5	7,5	7	6			
	16	12	12	10,5	9	7,5	6	
HDPE	10	7,5	6					
	16	12	9,5	6				

ABBREVIATIONS
PVC Polyvinyl chloride
ABS Acrylonitrile – butadiene – styrene
HDPE High density polyethylene

Table 10.5.2 Typical temperature and pressure limits for glassfibre reinforced epoxy (GRE) and polyester (GRP) pipes

Minimum heat distortion temperature of resin	Nominal pressure, bar	Maximum permissible working pressure, bar							
		–50 to 30°C	40°C	50°C	60°C	70°C	80°C	90°C	95°C
80°C	10	10	9	7,5	6				
	16	16	14	12	9,5				
	25	16	16	16	15				
100°C	10	10	10	9,5	8,5	7	6		
	16	16	16	15	13,5	11	9,5		
	25	16	16	16	16	16	15		
135°C	10	10	10	10	10	9,5	8,5	7	6
	16	16	16	16	16	15	13,5	11	9,5
	25	16	16	16	16	16	16	16	15

5.4 Fire performance criteria

5.4.1 Where plastics pipes are used in systems essential to the safe operation of the ship, or for containing combustible liquids or outboard water where leakage or failure could result in fire or in the flooding of watertight compartments, the pipes and fittings are to be of a type which have been fire endurance tested in accordance with the requirements of Table 10.5.3.

5.4.2 All pipes, except those fitted on open decks and within tanks, cofferdams, void spaces, pipe tunnels and ducts are to have low flame spread characteristics as determined by an acceptable test procedure.

5.4.3 Pipes within accommodation, service and control spaces are not to be capable of producing excessive quantities of smoke and toxic products.

5.4.4 Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance standards required, the coating is to be resistant to products likely to come into contact with the piping and be suitable for the intended application.

5.5 Electrical conductivity

5.5.1 Where a piping system is required to be electrically conductive for the control of static electricity, the resistance per unit length of the pipe, bends, elbows, fabricated branch pieces, etc., is not to exceed 0,1 MΩ/m. *See also* 5.2.4.

5.5.2 Electrical continuity is to be maintained across the joints and fittings and the system is to be earthed. *See also* Pt 6, Ch 2, 1.7. The resistance to earth from any point in the piping system is not to exceed 1 MΩ.

5.6 Manufacture and quality control

5.6.1 All materials for plastics pipes and fittings are to be approved by LR, and are in general to be tested in accordance with Ch 14, 4 of the Rules for Materials.

5.6.2 The material manufacturer’s test certificate, based on actual tested data, is to be provided for each batch of material.

Table 10.5.3 Fire endurance requirements (*see continuation*)

Piping systems	Location										
	A Machinery spaces of Category A	B Other Machinery spaces and pump rooms	C Cargo pump rooms	D Ro/ro cargo holds	E Other dry cargo holds	F Cargo tanks	G Fuel oil tanks	H Ballast water tanks	I Cofferdams void spaces pipe tunnel and ducts	J Accommodation service and control spaces	K Open decks
CARGO (FLAMMABLE CARGOES (f.p. ≤55°C)											
1 Cargo lines	N/A	N/A	L1	N/A	N/A	0	N/A	0[10]	0	N/A	L1[2]
2 Crude oil washing lines	N/A	N/A	L1	N/A	N/A	0	N/A	0[10]	0	N/A	L1[2]
3 Vent lines	N/A	N/A	N/A	N/A	N/A	0	N/A	0[10]	0	N/A	X
INERT GAS											
4 Water seal effluent line	N/A	N/A	0[1]	N/A	N/A	0[1]	0[1]	0[1]	0[1]	N/A	0
5 Scrubber effluent line	0[1]	0[1]	N/A	N/A	N/A	N/A	N/A	0[1]	0[1]	N/A	0
6 Main line	0	0	L1	N/A	N/A	N/A	N/A	N/A	0	N/A	L1[6]
7 Distribution lines	N/A	N/A	L1	N/A	N/A	0	N/A	N/A	0	N/A	L1[2]
FLAMMABLE LIQUIDS (f.p. >55°C)											
8 Cargo lines	X	X	L1	X	X	N/A[3]	0	0[10]	0	N/A	L1
9 Fuel oil	X	X	L1	X	X	N/A[3]	0	0	0	L1	L1
10 Lubricating oil	X	X	L1	X	X	N/A	N/A	N/A	0	L1	L1
11 Hydraulic oil	X	X	L1	X	X	0	0	0	0	L1	L1
OUTBOARD WATER[1]											
12 Bilge main and branches	L1[7]	L1[7]	L1	X	X	N/A	0	0	0	N/A	L1
13 Fire main and water spray	L1	L1	L1	X	N/A	N/A	N/A	0	0	X	L1

Table 10.5.3 Fire endurance requirements *(continued)*

Piping systems	A Machinery spaces of Category A	B Other Machinery spaces and pump rooms	C Cargo pump rooms	D Ro/ro cargo holds	E Other dry cargo holds	F Cargo tanks	G Fuel oil tanks	H Ballast water tanks	I Cofferdams void spaces pipe tunnel and ducts	J Accommodation service and control spaces	K Open decks
	Location										
14 Foam system	L1	L1	L1	N/A	N/A	N/A	N/A	N/A	0	L1	L1
15 Sprinkler system	L1	L1	L3	X	N/A	N/A	N/A	0	0	L3	L3
16 Ballast	L3	L3	L3	L3	X	0[10]	0	0	0	L2	L2
17 Cooling water, essential services	L3	L3	N/A	N/A	N/A	N/A	N/A	0	0	N/A	L2
18 Tank cleaning services fixed machines	N/A	N/A	L3	N/A	N/A	0	N/A	0	0	N/A	L3[2]
19 Non-essential systems	0	0	0	0	0	N/A	0	0	0	0	0
FRESHWATER											
20 Cooling water essential services	L3	L3	N/A	N/A	N/A	N/A	0	0	0	L3	L3
21 Condensate return	L3	L3	L3	0	0	N/A	N/A	N/A	0	0	0
22 Non-essential systems	0	0	0	0	0	N/A	0	0	0	0	0
SANITARY/DRAINS/ SCUPPERS											
23 Deck drains (internal)	L1[4]	L1[4]	N/A	L1[4]	0	N/A	0	0	0	0	0
24 Sanitary drains (internal)	0	0	N/A	0	0	N/A	0	0	0	0	0
25 Scuppers and discharges (overboard)	0[1,8]	0[1,8]	0[1,8]	0[1,8]	0[1,8]	0	0	0	0	0[1,8]	0
SOUNDING/AIR											
26 Water tanks/dry spaces	0	0	0	0	0	0[10]	0	0	0	0	0[11]

Table 10.5.3 Fire endurance requirements *(continued)*

Piping systems	Location										
	A Machinery spaces of Category A	B Other Machinery spaces and pump rooms	C Cargo pump rooms	D Ro/ro cargo holds	E Other dry cargo holds	F Cargo tanks	G Fuel oil tanks	H Ballast water tanks	I Cofferdams void spaces pipe tunnel and ducts	J Accommodation service and control spaces	K Open decks
27 OIL TANKS (f.p. > 55°C)	X	X	X	X	X	X[3]	0	0[10]	0	X	X
MISCELLANEOUS 28 Control air	L1[5]	L1[5]	L1[5]	L1[5]	L1[5]	N/A	0	0	0	L1[5]	L1[5]
29 Service air (non-essential)	0	0	0	0	0	N/A	0	0	0	0	0
30 Brine	0	0	N/A	0	0	N/A	N/A	N/A	0	0	0
31 Auxiliary low pressure steam (≤ 7 bar)	L2	L2	0[9]	0[9]	0[9]	0	0	0	0	0[9]	0[9]

LOCATION DEFINITIONS

	Location	Definition
A	Machinery spaces of Category A	Machinery spaces of Category A as defined in SOLAS* regulation II–2/3.19.
B	Other machinery spaces and pump rooms	Spaces, other than Category A machinery spaces and cargo pump rooms, containing propulsion machinery, boilers, steam and internal combustion engines, generators and major electrical machinery, pumps, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces.
C	Cargo pump rooms	Spaces containing cargo pumps and entrances and trunks to such spaces.
D	Ro-ro cargo holds	Ro-ro cargo holds are ro-ro cargo spaces and special category spaces as defined in SOLAS* regulation II–2/3.14 and 3.18.
E	Other dry cargo holds	All spaces other than ro-ro cargo holds used for non-liquid cargo and trunks to such spaces.
F	Cargo tanks	All spaces used for liquid cargo and trunks to such spaces.
G	Fuel oil tanks	All spaces used for fuel oil (excluding cargo tanks) and trunks to such spaces.
H	Ballast water tanks	All spaces used for ballast water and trunks to such spaces.
I	Cofferdams, voids, etc.	Cofferdams and voids are those empty spaces between two bulkheads separating two adjacent compartments.
J	Accommodation, service	Accommodation spaces, service spaces and control stations as defined in SOLAS* regulation II–2/3.10, 3.12, 3.22.
K	Open decks	Open deck spaces, as defined in SOLAS* regulation II–2/26.2.2(5).

* SOLAS 74 as amended by the 1978 SOLAS Protocol and the 1981 and 1983 amendments (consolidated text).
(A Category A machinery space is a machinery space containing internal combustion machinery for main propulsion or, internal combustion machinery used for purposes other than main propulsion where such machinery has a total power of not less than 375 kW or, containing any oil fired boiler or oil fuel unit, or any other oil-fired equipment other than boilers).

ABBREVIATIONS

- L1 Fire endurance test in dry conditions, 60 minutes, IMO Resolution A.753(18) Appendix 1.
- L2 Fire endurance test in dry conditions, 30 minutes, IMO Resolution A.753(18) Appendix 1.
- L3 Fire endurance test in wet conditions, 30 minutes, IMO Resolution A.753(18) Appendix 2.
- 0 No fire endurance test required.
- N/A Not applicable.
- X Metallic materials having a melting point greater than 925°C.

Table 10.5.3 Fire endurance requirements *(conclusion)*

NOTES

1. Where non-metallic piping is used, remotely controlled valves to be provided at ship's side (valve is to be controlled from outside space).
2. Remote closing valves to be provided at the cargo tanks.
3. When cargo tanks contain flammable liquids with f.p. > 55°C, '0' may replace 'N/A' or 'X'.
4. For drains serving only the space concerned, '0' may replace 'L1'.
5. When controlling functions are not required by the Rules or statutory requirements, '0' may replace 'L1'.
6. For pipe between machinery space and deck water seal, '0' may replace 'L1'.
7. For passenger vessels, 'X' is to replace 'L1'.
8. Scuppers serving open decks should be 'X' throughout.
9. For essential services, such as fuel oil tank heating and ship's whistle, 'X' is to replace '0'.
10. Air and sounding pipes on open deck are to be of substantial construction, *see* Pt 5, Ch 11,10.2.1.

5.6.3 Plastics pipes and fittings are to be manufactured at a works approved by LR in accordance with agreed quality control procedures which shall be capable of detecting at any stage (e.g. incoming material, production, finished article, etc.) deviations in the material, product or process.

5.6.4 Plastics pipes are to be manufactured and tested in accordance with Ch 14, 4 of the Rules for Materials. For Class III piping systems, the pipe manufacturer's test certificate may be accepted in lieu of an LR Certificate and is to be provided for each consignment of pipe.

5.7 Installation and construction

5.7.1 All pipes are to be adequately but freely supported. Suitable provision is to be made for expansion and contraction to take place without unduly straining the pipes.

5.7.2 Pipes may be joined by mechanical couplings or by bonding methods such as welding and laminating.

5.7.3 Where bonding systems are used, the manufacturer or installer shall provide a written procedure covering all aspects of installation, including temperature and humidity conditions. The bonding procedure is to be approved by LR.

5.7.4 The person carrying out the bonding is to be qualified. Records are to be available to the Surveyor for each qualified person showing the bonding procedure and performance qualification, together with dates and results of the qualification testing.

5.7.5 In the case of pipes intended for essential services each qualified person is, at the place of construction, to make at least one test joint, representative of each type of joint to be used. The joined pipe section is to be tested to an internal hydrostatic pressure of four times the design pressure of the pipe system and the pressure held for not less than one hour, with no leakage or separation of joints. The bonding procedure test is to be witnessed by the Surveyor.

5.7.6 Conditions during installation, such as temperature and humidity, which may affect the strength of the finished joints, are to be in accordance with the agreed bonding procedure.

5.7.7 The required fire endurance level of the pipe is to be maintained in way of pipe supports, joints and fittings, including those between plastics and metallic pipes.

5.7.8 Where piping systems are arranged to pass through watertight bulkheads or decks, provision is to be made for maintaining the integrity of the bulkhead or deck by means of metallic bulkhead, or deck pieces. The bulkhead pieces are to be of substantial construction and suitably protected against corrosion and so constructed to be of a strength equivalent to the intact bulkhead; attention is drawn to 5.7.1, *see also* Pt 5, Ch 11,2.4.1. Details of the arrangements are to be submitted for approval. *See also* Pt 6, Ch 3,9.

5.8 Testing

5.8.1 The hydraulic testing of pipes and fittings is to be in accordance with Section 9.

5.8.2 Where a piping system is required to be electrically conductive, tests are to be carried out to verify that the resistance to earth from any point in the system does not exceed 1 MΩ. *See also* Pt 6, Ch 2,17.3.

Section 6 Stainless steel

6.1 General

6.1.1 Stainless steels may be used for a wide range of services and are particularly suitable for use at elevated temperatures. For guidance on the use of stainless steels in outboard water systems *see* 10.3.4.

6.1.2 The minimum thickness of stainless steel pipes is to be determined from the formula given in 2.2.4 or 2.2.5 using a corrosion allowance of 0,8 mm. Values of the 0,2 per cent proof stress and tensile strength of the material for use in the formula in 2.2.1 may be obtained from Table 6.5.2 in Chapter 6 of the Rules for Materials.

6.1.3 Where stainless steel is used in lubricating and hydraulic oil systems, the corrosion allowance may be reduced to 0.3 mm.

6.1.4 In no case is the thickness of the stainless steel pipes is to be less than that shown in Table 10.6.1.

Table 10.6.1 Minimum thickness for stainless steel pipes

Standard pipe sizes (outside diameter)			Minimum nominal thickness
mm	to	mm	mm
8,0	to	10,0	0,8
12,0	to	20,0	1,0
25,0	to	44,5	1,2
50,0	to	76,1	1,5
88,9	to	108,0	2,0
133,0	to	159,0	2,5
193,7	to	267,0	3,0
273,0	to	457,2	3,5

6.1.5 Joints in stainless steel pipe work may be made by any of the techniques described in 2.3.

6.1.6 Where pipe work is butt welded, this should preferably be accomplished without the use of backing rings, in order to eliminate the possibility of crevice corrosion between the backing ring and the pipe.

Section 7 Valves

7.1 Design requirements

7.1.1 The design, construction and operational capability of valves is to be in accordance with an acceptable National or International Standard appropriate to the piping system. Where valves are not in accordance with an acceptable standard, details are to be submitted for consideration. Where valves are fitted, the requirements of 7.1.2 to 7.1.15 are to be satisfied.

7.1.2 Valves are to be made of steel, cast iron, copper alloy, or other approved material suitable for the intended purpose.

7.1.3 Valves having isolation or sealing components sensitive to heat are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or the loss of an essential service.

7.1.4 Where valves are required to be capable of being closed remotely in the event of fire, the valves, including their control gear, are to be of steel construction or of an acceptable fire tested design.

7.1.5 Valves are to be arranged for clockwise closing and are to be provided with indicators showing whether they are open or shut unless this is readily obvious.

7.1.6 Valves and cocks are to be fitted with legible nameplates, and, unless otherwise specifically mentioned in the Rules the valves and cocks are to be fitted in places where they are at all times readily accessible.

7.1.7 Valves are to be so constructed as to prevent the possibility of valve covers or glands being slackened back or loosened when the valves are operated.

7.1.8 Valves are to be used within their specified pressure and temperature rating for all normal operating conditions, and are to be suitable for the intended purpose.

7.1.9 Valves intended for submerged installation are to be suitable for both internal and external media. Spindle sealing is to prevent ingress of external media at the maximum external pressure head expected in service.

7.1.10 The controls of butterfly and ball valves of the ‘swing through type’ are to be provided with suitable means (such as a gearbox) to prevent this.

7.1.11 Additional requirements for shell valves are given in Ch 11,2.5.

7.1.12 Additional requirements for valves with remote control are given in Ch 11,2.3.

7.1.13 Where the valves are of the diaphragm type, they are not acceptable as shut-off valves at the shell plating.

7.1.14 Resiliently seated valves are not to be used in main or auxiliary machinery spaces as branch or direct bilge suction valves or as pump suction valves from the main bilge line (except where the valve is located in the immediate vicinity of the pump and in series with a metal seated non-return valve. The non-return valve is to be fitted on the bilge main side of the resiliently seated valve). When they are used in other locations and within auxiliary machinery spaces having little or no fire risk they should be of an approved fire safe type and used in conjunction with a metal seated non-return valve.

7.1.15 Resiliently seated valves are not acceptable for use in the fire water mains unless they have been satisfactorily fire tested.

■ *Section 8* **Flexible hoses**

8.1 FGeneral

8.1.1 A flexible hose assembly is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

8.1.2 For the purpose of approval for the applications in 8.2, details of the materials and construction of the hoses, and the method of attaching the end fittings together with evidence of satisfactory prototype testing, are to be submitted for consideration.

8.1.3 The use of hose clamps and similar types of end attachments are not be used for flexible hoses in piping systems for steam, flammable media, starting air systems or for outboard water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 5 bar. The clips are to be of stainless steel and doubled at each connection. Means are to be provided to prevent the pipe from pulling out of the hose when under pressure.

8.1.4 Flexible hoses are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

8.1.5 Flexible hoses are not to be used to compensate for misalignment between sections of piping.

8.1.6 Flexible hose assemblies are not to be installed where they may be subjected to torsional deformation (twisting) under normal operating conditions.

8.1.7 The number of flexible hoses in piping systems mentioned in this Section is to be kept to a minimum and to be limited for the purpose stated in 8.2.1.

8.1.8 Where flexible hoses are intended for conveying flammable fluids in piping systems that are in close proximity to hot surfaces, electrical installation or other sources of ignition, the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other suitable protection.

8.1.9 Flexible hoses are to be installed in clearly visible and readily accessible locations.

8.1.10 The installation of flexible hose assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:
(a) Orientation.
(b) End connection support (where necessary).
(c) Avoidance of hose contact that could cause rubbing and abrasion.
(d) Minimum bend radii.

8.1.11 Flexible hoses are to be permanently marked by the manufacturer with the following details:
(a) Hose manufacturer's name or trademark.
(b) Date of manufacture (month/year).
(c) Designation type reference.
(d) Nominal diameter.
(e) Pressure rating.
(f) Temperature rating.
Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

8.1.12 For special requirements for hoses intended for use on board of Gas, Oil and Chemical Tankers, *see also* Ch 13,3.9.

8.2 Applications

8.2.1 Short joining lengths of flexible hoses complying with the requirements of this Section may be used, where necessary, to accommodate relative movement between various items of machinery connected to permanent piping systems. The requirements of this Section may also be applied to temporarily-connected flexible hoses or hoses of portable equipment.

8.2.2 Rubber or plastics hoses, with integral cotton or similar braid reinforcement, may be used in fresh and outboard cooling water systems. In the case of outboard-water systems, where failure of the hoses could give rise to the danger of flooding, the hoses are to be suitably enclosed, as indicated in Ch 11, 2.8.

8.2.3 Rubber or plastics hoses, with single or double closely woven integral wire braid or other suitable material reinforcement, or convoluted metal pipes with wire braid protection, may be used in bilge, ballast, compressed air, fresh water, outboard-water, oil fuel, lubricating oil, Class III steam and hydraulic and thermal oil systems.

8.2.4 Where synthetic rubber or plastics hoses are used for oil fuel supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid.

8.2.5 Flexible hoses for use in steam systems are to be of metallic construction.

8.2.6 Flexible hoses are not to be used in high pressure fuel oil injection systems.

8.2.7 The requirements in this Section for flexible hose assemblies are not applicable to hoses intended to be used in fixed fire-extinguishing systems.

8.3 Design requirements

8.3.1 Flexible hose assemblies are to be designed and constructed in accordance with recognised National or International Standards acceptable to LR.

8.3.2 Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. End connections which do not have flanges are to comply with 2.11 as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

8.3.3 Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by 8.4 are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

8.3.4 Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media, and outboard-water systems where failure may result in flooding, are to be of fire-resistant type. Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

8.3.5 Flexible hose assemblies are to be suitable for the intended location and application, taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any other applicable requirements in the Rules.

8.4 Testing

8.4.1 Acceptance of flexible hose assemblies is subject to satisfactory prototype testing. Prototype test programmes for flexible hose assemblies are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.

8.4.2 For a particular hose type complete with end fittings, the tests, as applicable, are to be carried out on different nominal diameters for pressure, burst, impulse and fire resistance in accordance with the requirements of the relevant standard. The following standards are to be used as applicable:

- ISO 6802 – *Rubber and plastics hoses and hose assemblies – Hydraulic pressure impulse test without flexing.*
- ISO 6803 – *Rubber and plastics hoses and hose assemblies – Hydraulic pressure impulse test with flexing.*
- ISO 15540 – *Ships and marine technology – Fire resistance of hose assemblies – Test methods.*
- ISO 15541 – *Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench.*
- ISO 10380 – *Pipe-work – Corrugated metal hoses and hose assemblies.*

Other standards may be accepted where agreed by LR.

8.4.3 All flexible hose assemblies are to be satisfactorily prototype burst tested to an international standard* to demonstrate they are able to withstand a pressure of not less than four times the design pressure without indication of failure or leakage.

NOTE
* The International Standards, e.g. EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at 4 x Maximum Working Pressure.

■ *Section 9* Hydraulic tests on pipes and fittings

9.1 Hydraulic tests before installation on board

9.1.1 All Class I and II pipes and their associated fittings are to be tested by hydraulic pressure to the Surveyor's satisfaction. Further, all steam, feed, compressed air and oil fuel pipes, together with their fittings, are to be similarly tested where the design pressure is greater than 3,5 bar. The test is to be carried out after completion of manufacture and before installation on board and where applicable, before insulating and coating.

9.1.2 The test pressure is to be 1,5 times the design pressure, as defined in 1.3.

9.1.3 All valve bodies are to be tested by hydraulic pressure to 1,5 times the nominal pressure rating at ambient temperature.

9.1.4 All valves are to be tested for tightness at 1,1 times the maximum permissible working pressure.

9.2 Testing after assembly on board

9.2.1 Heating coils in tanks and oil fuel piping are to be tested by hydraulic pressure, after installation on board, to 1,5 times the design pressure but in no case to less than 4 bar.

9.2.2 Where pipes specified in 9.1.1 are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of 9.1 after welding. The pipe lengths may be insulated, except in way of the joints made during installation and before the hydraulic test is carried out.

9.2.3 The hydraulic test required by 9.2.2 may be omitted provided non-destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results. Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have a prejudicial effect on the service performance of the piping.

9.2.4 Where bilge pipes are accepted in way of double bottom tanks or deep tanks, *see* Ch 11,7.7 and 7.8, the pipes after fittings are to be tested by hydraulic pressure to the same pressure as the tanks through which they pass.

■ *Cross-references*

See also Ch 11,2.9 for testing after installation.

■ *Section 10* **Guidance notes on metal pipes for water services**

10.1 General

10.1.1 These guidance notes, except where it is specifically stated, apply to outboard water piping systems.

10.1.2 In addition to the selection of suitable materials, careful attention should be given to the design details of the piping system and the workmanship in fabrication, construction and installation of pipework in order to obtain maximum life in service.

10.2 Materials

10.2.1 Materials used in outboard water piping systems include:

- Galvanized steel.
- Steel pipes lined with rubber, plastics or stoved coatings.
- Copper.
- 90/10 copper-nickel-iron.
- 70/30 copper-nickel.
- Aluminium brass.

10.2.2 Selection of materials should be based on:

- The ability to resist general and localized corrosion, such as pitting, impingement attack and cavitation throughout all the flow velocities likely to be encountered;
- Compatibility with the other materials in the system, such as valve bodies and casings (e.g. in order to minimise bimetallic corrosion);
- The ability to resist selective corrosion, e.g. dezincification of brass, dealuminification of aluminium brass and graphitization of cast iron;
- The ability to resist stress corrosion and corrosion fatigue; and
- The amenability to fabrication by normal practices.

10.3 Steel pipes

10.3.1 Steel pipes should be protected against corrosion, and protective coatings should be applied on completion of all fabrication, i.e. bending, forming and welding of the steel pipes.

10.3.2 Welds should be free from lack of fusion and crevices. The surfaces should be dressed to remove slag and spatter and this should be done before coating. The coating should be continuous around the ends of the pipes and on the faces of flanges.

10.3.3 Galvanizing the bores and flanges of steel pipes as protection against corrosion is common practice, and is recommended as the minimum protection for pipes in overboard water systems, including those for bilge and ballast service.

10.3.4 Austenitic stainless steel pipes are not recommended for brackish or salt water services as they are prone to pitting, particularly in polluted waters.

10.3.5 Rubber lined pipes are effective against corrosion and suitable for higher water velocities. The rubber lining should be free from defects, e.g. discontinuities, pinholes, etc., and it is essential that the bonding of the rubber to the bore of the pipe and flange face is sound. Rubber linings should be applied by firms specializing in this form of protection.

10.3.6 The foregoing comments on rubber lined pipes also apply to pipes lined with plastics.

10.3.7 Stove coating of pipes as protection against corrosion should only be used where the pipes will be efficiently protected against mechanical damage.

10.4 Copper and copper alloy pipes

10.4.1 Copper pipes are particularly susceptible to perforation by corrosion/erosion and should only be used for low water velocities and where there is no excessive local turbulence.

10.4.2 Aluminium brass and copper-nickel-iron alloy pipes give good service in reasonably clean overboard water. For service with polluted river or harbour waters, copper-nickel-iron alloy pipes with at least 10 per cent nickel are preferable. Alpha brasses, i.e. those containing 70 per cent or more copper, must be inhibited effectively against dezincification by suitable additions to the composition. Alpha beta-brasses, i.e. those containing less than 70 per cent copper, should not be used for pipes and fittings.

10.4.3 New copper alloy pipes should not be exposed initially to polluted water. Clean overboard water should be used at first to allow the metals to develop protective films. If this is not available the system should be filled with inhibited town mains water.

10.5 Flanges

10.5.1 Where pipes are exposed to sea water on both external and internal surfaces, flanges should be made, preferably, of the same material. Where overboard water is confined to the bores of pipes, flanges may be of the same material or of a less noble metal than that of the pipe, *see also* 2.3.

10.5.2 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or by capillary silver brazing. Where welding is used, the fillet weld at the back should be a strength weld and that in the face, a seal weld.

10.5.3 Inert gas shielded arc welding is the preferred process but metal arc welding may be used on copper-nickel-iron alloy pipes.

10.5.4 Mild steel flanges may be attached by argon arc welding to copper-nickel-iron pipes and give satisfactory service, provided that no part of the steel is exposed to the sea water.

10.5.5 Where silver brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing should contain not less than 49 per cent silver.

10.5.6 The use of a copper-zinc brazing alloy is not permitted.

10.6 Water velocity

10.6.1 Water velocities should be carefully assessed at the design stage and the materials of pipes, valves, etc., selected to suit the conditions.

10.6.2 The water velocity in copper pipes should not exceed 1 m/s.

10.6.3 The water velocity in the pipes of the materials below should normally be not less than about 1 m/s in order to avoid fouling and subsequent pitting, but should not be greater than the following:

Galvanized steel	3,0 m/s
Aluminium brass	3,0 m/s
90/10 copper-nickel-iron	3,5 m/s
70/30 copper-nickel	5,0 m/s

10.7 Fabrication and installation

10.7.1 Attention should be given to ensuring streamlined flow and reducing entrained air in the system to a minimum. Abrupt changes in the direction of flow, protrusions into the bores of pipes and other restrictions of flow should be avoided. Branches in continuous flow lines should be set at a shallow angle to the main pipe, and the junction should be smooth.

10.7.2 Pipe bores should be smooth and clean.

10.7.3 Jointing should be flush with the bore surfaces of pipes and misalignment of adjacent flange faces should be reduced to a minimum.

10.7.4 Pipe bends should be of as large a radius as possible, and the bore surface should be smooth and free from puckering at these positions. Any carbonaceous films or deposits formed on the bore surfaces during the bending processes should be carefully removed. Organic substances are not recommended for the filling of pipes for bending purposes.

10.7.5 The position of supports should be given special consideration in order to minimize vibration and ensure that excessive bending moments are not imposed on the pipes.

10.7.6 Systems should not be left idle for long periods, especially where the water is polluted.

10.7.7 Strainers should be provided at the inlet to sea water systems.

10.8 Metal pipes for fresh water services

10.8.1 Mild steel or copper pipes are normally satisfactory for service in fresh water applications. Hot fresh water, however, may promote corrosion of mild steel pipes unless the hardness and PH of the water are controlled.

10.8.2 Water with a slight salt content should not be left stagnant for long periods in mild steel pipes. Low salinity and the limited supply of oxygen in such conditions promote the formation of black iron oxide, and this may give rise to severe pitting. Where stagnant conditions are unavoidable, steel pipes should be galvanized, or pipes of suitable non-ferrous material used.

10.8.3 Copper alloy pipes should be treated to remove any carbonaceous films or deposits before the tubes are put into service.

10.8.4 Brass fittings and flanges in contact with water should be made of an alpha-brass effectively inhibited against dezincification by suitable additions to the composition.

10.8.5 Aluminium brass has been widely used as a material for heat exchanger and condenser tubes, but its use in 'once through' systems is not recommended since, under certain conditions, it is prone to pitting and cracking.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to piping systems on all types of Inland Waterway Vessels except where otherwise stated.

1.1.2 Special attention is drawn to National and International technical and operational requirements of countries where the ship is registered or operating and which are outside classification as defined in these Rules.

1.1.3 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules. Consideration will also be given to the pumping arrangements of small ships and ships to be assigned class notations for special services.

1.1.4 The Rules for bilge systems for dry cargo vessels carrying dangerous goods, have been derived from requirements of the **ADNR** Regulations of the Central Rhine Commission and the European provisions concerning the international Carriage of Dangerous Goods by Inland Waterways **ADN** which assume heavy traffic on relatively narrow waterways through heavily populated areas. ADN is an abbreviation from **A**ccord européen relative au transport international des merchandises **D**angereuses par voie de **N**avigation intérieure. The letter “R “ for ADNR is standing for **R**hin. *See also* Pt 4, Ch 1,12.

1.1.5 Where a **DG** notation is to be assigned, the requirements of this Chapter and Pt 4, Ch 1,1.3.5, are to be complied with.

1.2 Prevention of progressive flooding in damage condition

1.2.1 For ships to which subdivision and damage stability requirements apply, precautions are to be taken to prevent progressive flooding between compartments resulting from damage to piping systems. For this purpose, piping systems are to be located inboard of the assumed extent of damage applicable to the requirements of the Flag Administration.

1.2.2 Where it is not practicable to locate piping systems as required by 1.2.1, the following precautions are to be taken:

(a) Bilge suction pipes are to be provided with non-return valves of approved type.
(b) Other piping systems are to be provided with shut-off valves capable of being operated from positions accessible in the damage condition, or from above the bulkhead deck.

These valves are to be located in the compartment containing the open end or in a suitable position such that the compartment may be isolated in the event of damage to the piping system.

1.2.3 Where subdivision and damage stability requirements apply and where penetration of watertight divisions by pipes, ducts, trunks or other penetrations is necessary, arrangements are to be made to maintain the watertight integrity.

1.3 Plans and particulars

1.3.1 The following plans (in diagrammatic form) and particulars are to be submitted for approval. Additional plans should not be submitted unless the arrangements are of a novel or special character affecting classification:

- Arrangements of air pipes and closing devices for all tanks and enclosed spaces.
- Sounding arrangements for all tanks, enclosed spaces and cargo holds.
- Arrangements of level alarms fitted in tanks, cargo holds, machinery spaces, pump rooms and any other spaces.
- Arrangements of any cross flooding or healing tank systems.
- Bilge drainage arrangements for all compartments which are to include details of location, number and capacity of pumping units on bilge service.
- Ballast filling and drainage arrangements.
- Oil fuel pumping and spill/drainage arrangements.
- Arrangements for flooding holds together with blanking arrangements for bilge and ballast piping systems for bulk carriers having floodable holds.
- Details verifying compliance with the sizing of air pipes required by 10.8.
- Arrangements of oil fuel piping in connection with oil burning installations and oil fired galleys.
- Arrangement of boiler feed system.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil systems.
- Arrangements of flammable liquids used for power transmission, control and heating systems.

- Arrangements of cooling water systems for main and auxiliary services.
- Oil fuel tanks not forming part of the ship's structure.
- Arrangements and dimensions of all steam pipes, with details of flanges, bolts and weld attachments, and particulars of the material of pipes, flanges, bolts and electrodes.
- Arrangements and details of box coolers for main and auxiliary services.

■ *Section 2* Construction and installation

2.1 Materials

2.1.1 Except where otherwise stated in this Chapter, pipes, valves and fittings are to be made of steel, cast iron, copper, copper alloy, or other approved material suitable for the intended service.

2.1.2 Where applicable, the materials are to comply with the relevant requirements of Chapter 10.

2.1.3 Materials sensitive to heat, such as aluminium, lead or plastics, are not to be used in systems essential to the safe operation of the ship, or for containing combustible liquids or water where leakage or failure could result in fire or in the flooding of watertight compartments, *see* Chapter 10 for plastics pipes.

2.2 Pipe wall thicknesses

2.2.1 The minimum nominal wall thickness of steel, copper, copper alloy and stainless steel pipes is to be in accordance with Chapter 10.

2.2.2 Special consideration will be given to the wall thicknesses of pipes made of materials other than mentioned in 2.2.1.

2.3 Valves – Installation and control

2.3.1 Valves and cocks are to be fitted in places where they are at all times readily accessible, unless otherwise specifically mentioned in the Rules. Valves in cargo oil and ballast systems may be fitted inside tanks, subject to 2.3.2.

2.3.2 All valves which are provided with remote control are to be arranged for local manual operation, independent of the remote operating mechanism. For shipside valves and valves on the collision bulkhead, the means for local manual operation are to be permanently attached. For submerged valves in cargo oil and ballast systems, as permitted by 2.3.1, local manual operation may be by extended spindle or a portable hand pump. Where manual operation is by hand pump, the control lines to each submerged valve are to incorporate quick coupling connections, as close to the valve actuator as practicable, to allow easy connection of the hand pump. Not less than two hand pumps are to be provided.

2.3.3 In the case of valves which are required by the Rules to be provided with remote control, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

2.3.4 For general requirements of valves, *see* Ch 10,7.

2.4 Attachment of valves to watertight plating

2.4.1 Valve chests, cocks, pipes or other fittings attached directly to the plating of tanks and to bulkheads, which are required to be of watertight construction, are to be secured by means of studs screwed through the plating or by tap bolts, and not by bolts passing through clearance holes. Alternatively, the studs or the bulkhead pieces may be welded to the plating.

2.4.2 For requirements relating to valves on the collision bulkhead, *see* 3.5.3.

2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)

2.5.1 All water inlet and overboard discharge pipes are to be fitted with valves or cocks secured directly to the shell plating, or to the plating of fabricated steel water boxes attached to the shell plating. These fittings are to be secured by bolts tapped into the plating and fitted with countersunk heads, or by studs screwed into heavy steel pads fitted to the plating. The stud holes are not to penetrate the plating.

2.5.2 Valves for ship-side applications are to be installed such that the section of piping immediately inboard of the valve can be removed without affecting the watertight integrity of the hull.

2.5.3 Distance pieces of short, rigid construction, and made of approved material, may be fitted between the valves and shell plating. The thickness of such pipes is to be not less than:

(a) Shell thickness for pipes smaller or equal to NB 50.
(b) Shell thickness plus 2 mm for pipes greater than NB 50.

In addition to the above, the following conditions are to be met:

- Distance pieces are to be efficiently protected against corrosion.
- Distance pieces of steel may be welded to the shell plating.
- Details of the welded connections and of fabricated steel water boxes are to be submitted.

2.5.4 Gratings are to be fitted at all openings in the ship's side for inlet valves and inlet water boxes. The net area through the gratings is to be not less than twice that of the valves connected to the inlets.

2.5.5 Water inlet and overboard discharge valves and cocks are in all cases to be fitted in easily accessible positions, and so far as practicable, are to be readily visible. Indicators are to be provided local to the valves and cocks, showing whether they are open or shut. The valve spindles are to extend above the lower platform.

2.5.6 Ship-side valves and fittings, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

2.5.7 Valves, cocks and distance pieces, intended for installation on the ship's side below the load waterline, are to be tested by hydraulic pressure to not less than 5 bar.

2.6 Piping systems – Installation

2.6.1 Bilge, ballast and cooling water suction and discharge pipes are to be permanent pipes made in readily removable lengths with flanged joints, except as mentioned in 7.8, and are to be efficiently secured in position to prevent chafing or lateral movement. For joints in oil fuel piping systems, *see* Ch 12,4.4.

2.7 Provision for expansion

2.7.1 Suitable provision for expansion is to be made, where necessary, in each range of pipes.

2.7.2 Where expansion pieces are fitted, they are to be of an approved type and are to be protected against over extension and compression. The adjoining pipes are to be suitably aligned, supported, guided and anchored. Where necessary, expansion pieces of the bellows type are to be protected against mechanical damage.

2.7.3 Expansion pieces of an approved type incorporating special quality oil resistant rubber or other suitable synthetic material may be used in cooling water lines in machinery spaces. Where fitted in water inlet lines, they are to be provided with guards which will effectively enclose, but not interfere with, the action of the expansion pieces and will reduce to the minimum practicable any flow of water into the machinery spaces in the event of failure of the flexible elements. Proposals to use such fittings in water lines for other services will be specially considered when plans of the pumping systems are submitted for approval.

2.7.4 For requirements relating to flexible hoses, *see* Ch 10,8.

2.8 Miscellaneous requirements

2.8.1 All pipes situated in cargo spaces, chain lockers or other positions where they are liable to mechanical damage, are to be efficiently protected.

2.8.2 So far as is practicable, pipelines, including exhaust pipes from oil engines, are not to be led in the vicinity of switchboards or other electrical appliances. Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary. Short sounding pipes to tanks are not to terminate near electrical appliances, *see* 10.12.3.

2.9 Testing after installation

2.9.1 After installation on board, all steam, hydraulic, compressed air and other piping systems covered by 1.2.1, together with associated fittings which are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

■ *Cross-reference*

For guidance on metal pipes for water services, *see* Ch 10,10.

■ *Section 3*
Drainage of compartments, other than machinery spaces

3.1 General

3.1.1 All ships are to be provided with an efficient pumping plant having the suctions and means for drainage so arranged that any water within any compartment of the ship, or any watertight section of any compartment, can be pumped out through at least one suction when the ship is on an even keel and is either upright or has a list of not more than 5°. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

3.1.2 In passenger ships, the pumping plant is to be capable of draining any watertight compartment under all practicable conditions after a casualty, whether the ship is upright or listed.

3.1.3 In the case of dry compartments, the suctions required by 3.1.1 are, except where otherwise stated, to be branch bilge suctions, i.e. suctions connected to a main bilge line.

3.1.4 Void spaces which are permanently sealed need not be connected to the bilge system, *see also* Ch 10,2.2.6.

3.1.5 For drainage arrangements of non-self-propelled ships, *see* Section 9.

3.1.6 For additional drainage arrangements on ferries and Roll on-Roll off ships, *see* Pt 4, Ch 2.

3.2 Cargo holds

3.2.1 In ships having only one hold, and this being over 30 m in length, bilge suctions are to be fitted in suitable positions in the fore and after sections of the hold.

3.2.2 In ships having flat bottoms with a breadth exceeding 5 m, bilge suctions are to be fitted in the wings.

3.2.3 Where close ceilings or continuous gusset plates are fitted over the bilges, arrangements are to be made whereby water in a hold compartment may find its way to the suction pipes.

3.2.4 In ships fitted with double bottoms, suitably located bilge wells are to be provided.

3.2.5 For cargo holds having non-weathertight hatch covers or where hatch covers have been omitted, drainage arrangements are to take into account the effects of additional water ingress into the hold(s). Such ships shall meet the requirements of 3.2.6 to 3.2.9. *See* 6.3.2 for required bilge capacities.

3.2.6 High level bilge alarms are to be provided in cargo holds.

3.2.7 One of the bilge pumps dealing with the hold should be located in such a way that it will not be affected by a fire or other casualty to the space containing the other pump or the space containing the main source of power. This requirement is not applicable for pumps situated aft and forward in the cargo hold.

3.2.8 The above bilge pump should be supplied from a source of power other than the main source.

3.2.9 The bilge pumping system, including the piping system, should incorporate sufficient redundancy features so that the system will be fully operational and capable of dewatering the hold space(s) at the required capacity in the event of failure of one system component.

3.2.10 Drainage arrangements of cargo holds intended for the carriage of flammable or toxic liquids are to be independent of the bilge system(s) in the machinery space(s) and such ships shall meet the requirements of 3.2.11 to 3.2.18.

3.2.11 Arrangements for the carriage of dangerous goods are to be in compliance with (Inter)National requirements and acceptable to the relevant Administration.

3.2.12 Drainage arrangements of cargo holds in double hull ships may be achieved by the installation of fixed submersible pumps fitted in the cargo hold(s) as per 6.6, with a capacity as per 6.3 and with d_m calculated as a branch bilge suction in compliance with 5.2.1. Not less than two pumps are to be fitted crosswise in the cargo hold, i.e. one pump aft SB and one pump forward PS, or the other way around.

3.2.13 The discharge of the bilge pumps is preferably led directly overboard but may be led through the machinery space if the pipe is seamless and the circumferential welds are butt welds of the full penetration type and no other connections will be fitted in way of the machinery space. Flange connections in the piping are only permitted at the hull connection.

3.2.14 The fixed submersible pumps are to be accessible under all conditions of normal service.

3.2.15 The prime mover of the submersible pumps is to be of the intrinsically safe type when carrying flammable cargoes.

3.2.16 An additional emergency means of pumping is to be provided which may be a portable submersible self-priming pump with a capacity of not less than that required by 3.2.12. If the required capacity is such that the portability of the pump is no longer practicable, consideration should be given to divide the required capacity equally over two portable pumps. For storage of the portable pump(s), *see* 4.2.3.

3.2.17 Alternatively, drainage arrangements of the hold by means of two ejectors situated in the hold driven by pumps in the engine room(s) will be specially considered.

3.2.18 For single hull ships, the independent bilge system is to comply with the regular requirements as applicable for a cargo hold. Alternatively, a drainage arrangement as per 3.2.17 may be installed.

3.3. Flooding of holds

3.3.1 Flooding of the hold may be provided with a (dedicated) pump situated in the engine room(s).

3.3.2 During the carriage of dangerous goods, the connection with the hold is to be blinded off.

3.3.3 The Owners shall be informed that the stability of the vessel with a flooded hold shall be maintained under all conditions of service.

3.4 Tanks

3.4.1 All tanks (including double bottom tanks), whether used for water ballast, oil fuel or liquid cargoes, are to be provided with suction pipes, led to suitable power pumps, from the after end of each tank.

3.4.2 In general, the drainage arrangements are to be in accordance with 3.1. However, where the tanks are divided by longitudinal watertight bulkheads or girders into two or more tanks, a single suction pipe, led to the after end of each tank, will normally be acceptable.

3.4.3 The pumping arrangements for tanks that are intended to carry cargo oil having a flash point of 55°C or above, are also to comply with the requirements of Chapter 12, Sections 2, 3 and 4, so far as they are applicable.

3.5 Fore and after peaks

3.5.1 Where the peaks are used as tanks, a power pump suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, where hand pumps may be used.

3.5.2 Where the peaks are not used as tanks, and main bilge line suctions are not fitted, drainage of both peaks may be effected by hand pump suctions. Drainage of the after peak may be effected by means of a self-closing cock fitted in a well lighted and readily accessible position.

3.5.3 Except as permitted by 3.5.4, the collision bulkhead in passenger ships is not to be pierced below the bulkhead deck by more than one pipe for dealing with the contents of the fore peak. The pipe is to be provided with a screw-down valve capable of being operated from an accessible position above the bulkhead deck, the chest being secured to the bulkhead inside the fore peak. An indicator is to be provided to show whether the valve is open or closed.

3.5.4 Where the forepeak in a passenger ship is divided into two compartments, the collision bulkhead may be pierced below the bulkhead deck by two pipes (i.e. one for each compartment) provided there is no practicable alternative to the fitting of a second pipe. Each pipe is to be provided with a screw-down valve, fitted and controlled as in 3.5.3.

3.5.5 In ships other than passenger ships, pipes piercing the collision bulkhead are to be fitted with suitable valves operable from above the freeboard deck and the valve chests are to be secured to the bulkhead inside the forepeak. The valve may be fitted on the after side of the collision bulkhead, without remote control, provided that the valve is readily accessible under all service conditions and the space in which it is located is not a cargo space.

3.6 Spaces above fore peaks, after peaks and machinery spaces

3.6.1 Provision is to be made for the drainage of the chain locker and watertight compartments above the fore peak tank by hand or power pump bilge suctions. The chain locker is not to be drained into the fore peak.

3.6.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage, either by hand or power pump bilge suctions.

3.6.3 Subject to special approval of any applicable subdivision requirements, the compartments referred to in 3.6.2 may be drained by scuppers of not less than 38 mm bore, discharging to the machinery space and fitted with self-closing cocks situated in well lighted and visible positions.

3.6.4 Accommodation spaces which overhang the machinery space, may also be drained as in 3.6.3.

3.7 Maintenance of integrity of bulkheads

3.7.1 The intactness of the machinery space bulkheads, required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to the machinery space from adjacent compartments which are situated below the bulkhead deck.

3.7.2 No drain valve or cock is to be fitted to the collision bulkhead. Drain valves or cocks are not to be fitted to other watertight bulkheads if alternative means of drainage are practicable.

■ *Section 4*
Bilge drainage of machinery space

4.1 General

4.1.1 The bilge drainage arrangements in the machinery space are to comply with 3.1, except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the ship is on an even keel, and is either upright or has a list of not more than 5°. One of these suctions may be a branch bilge suction, i.e. a suction connected to the main bilge line, and the other is to be a direct bilge suction, i.e. a suction led direct to an independent power pump. An example of the necessary arrangements is detailed in 4.1.3.

4.1.2 In passenger ships, the drainage arrangements are to be such that machinery spaces can be pumped out under all practical conditions after a casualty, whether the ship is upright or listed.

4.1.3 In ships in which the propelling machinery is situated at the after end of the ship, it will generally be necessary for bilge suctions to be fitted in the forward wings as well as in the after end of the machinery space, but each case will be dealt with according to the size and structural arrangements of the compartment.

4.2 Submersible pump drainage

4.2.1 For ships other than passenger ships where a bilge main is not fitted, the branch bilge suction referred to in 4.1.1 and 4.1.3 may be replaced by a suction from fixed installed submersible pumps in accordance with 6.6. The second bilge suction is to be either a second fixed installed submersible bilge pump or a direct bilge suction as detailed in 5.3.

4.2.2 An emergency means of pumping out the compartment is to be provided where fixed submersible pumps will be fitted. The emergency bilge pumping arrangements may be provided by a portable submersible self-priming pump of a capacity not less than that required by 6.3.

4.2.3 The pump referred to in 4.2.2 together with its suction and delivery hoses is to be stored in a secure and safe locker marked ‘For emergency use only’, accessible from open deck and clear of the machinery space(s). The pump is to be available for immediate use. If the pump is electrically driven, it is to be supplied from the emergency switchboard.

4.3 Branch bilge suction arrangements connected to non-isolated bilge main

4.3.1 For ships other than passenger ships where the bilge main is not separated as per 7.2.1, the branch bilge suctions referred to in 4.1.1 and 4.1.3 may be connected to the common suction pipe between the two bilge pumps, provided one automatic non-return-valve and one additional screw-down non-return valve will be fitted in each branch bilge suction.

■ *Section 5* Sizes of bilge suction pipes

5.1 Main bilge line

5.1.1 The diameter, d_m, of the main bilge line is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter to be less than that required for any branch bilge suction:

$$d_m = 1{,}5\sqrt{L(B + D)} + 25 \text{ mm}$$

where

d_m = internal diameter of main bilge line, in mm
L = Rule length of ship as defined in Pt 3, Ch 1,6.1, in metres
B = greatest moulded breadth of ship, in metres
D = moulded depth of bulkhead deck, in metres.

5.2 Branch bilge suctions to cargo and machinery spaces

5.2.1 The diameter, d_b, of branch bilge line suction pipes to cargo and machinery spaces is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter of any suction to be less than 40 mm:

$$d_b = 2{,}0\sqrt{C(B + D)} + 25 \text{ mm}$$

where

d_b = internal diameter of branch bilge suction, in mm
C = length of compartment, in metres
B and D are as defined in 5.1.1.

5.3 Direct bilge suctions

5.3.1 The direct bilge suction in the machinery space required by 4.1.1 and referred to in 4.2.1. and 5.5.2 is to be led to the largest independent power pump, and the arrangements are to be such that the direct suction can be used independently of the main bilge suctions.

5.3.2 The size of the direct bilge suction required by 4.1.1 is to be not less than that determined by 5.1.1 or 5.4.1, as applicable when connected to a power pump, and by 5.2.1 when connected to a hand pump in case of ships having engines not exceeding 220 kW.

5.4 Main bilge line – Tankers and dry cargo ships having machinery spaces with their own bilge arrangements

5.4.1 In tankers and ships, where the engine room pumps do not deal with bilge drainage outside the machinery space, the diameter of the main bilge is to be not less than that required by the following formula, to the nearest 5 mm, but in no case is the diameter to exceed that required for the main bilge suction as per 5.1.1:

$$d_m = 3{,}1\sqrt{C(B + D)} + 25 \text{ mm}$$

where

C, B and D are as defined in 5.1.1 and 5.2.1.

5.5 Separate machinery spaces

5.5.1 The number and position of the branch bilge suctions in auxiliary engine rooms are to be the same as for cargo holds, *see* 3.2.

5.5.2 In addition to the branch bilge suctions, required by 5.5.1, at least one independent power pump direct bilge suction is to be fitted in each compartment. Similar provision is to be made in separate motor rooms of electrically propelled ships.

5.5.3 In ships other than passenger ships where a bilge main is not fitted and the auxiliary machinery space is served by fixed installed submersible pumps in accordance with 6.6, an additional emergency means of pumping out the compartment is to be provided, *see* 4.2.2 and 4.2.3.

5.5.4 In ships other than passenger ships, branch bilge suctions may be arranged as per 4.3.

5.5.5 In passenger ships, each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suctions are required in any one space. Where two or more suctions are provided, there is to be at least one suction at each side of the space.

5.5.6 For the number of bilge pumps to be installed in separate machinery spaces, *see* 6.1.2.

5.6 Distribution chest branch pipes

5.6.1 The area of each branch pipe connecting the bilge main to a distribution chest is to be not less than the sum of the areas required by the Rules for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

Section 6
Pumps on bilge service and their connections

6.1 Number of pumps

6.1.1 In ships with engines up to 220 kW, at least one power bilge pump is to be provided which may be worked from the main engine. In addition, hand pump suctions are to be fitted. In ships with engines exceeding 220 kW, at least two power bilge pumps are to be provided in the machinery space, one of which may be worked from the main engines and the other is to be independently driven.

6.1.2 For separate machinery spaces, not connected to a common bilge system and with installed auxiliary engines up to 220 kW, at least one power bilge pump is to be provided which may be worked from the auxiliary engine. In addition, hand pump suctions are to be fitted. For installed auxiliary engines exceeding 220 kW, at least two power bilge pumps are to be provided in the machinery space, one of which may be worked from the auxiliary engines and the other is to be independently driven.

6.1.3 In ships other than passenger ships, a bilge ejector in combination with a high pressure overboard water pump may be accepted as a substitute for an independent bilge pump as required by 6.1.1.

6.1.4 For small passenger ships, additional independent power bilge pumps may be required, depending on the size of the ship and the proposed service.

6.1.5 For passenger ships with a Rule length exceeding 80 m, at least three power bilge pumps are to be provided, one of which may be operated from the main engines.

6.1.6 For location of pumps on passenger ships, *see* 8.1.

6.2 General service pumps

6.2.1 The bilge pumps required by 6.1, may also be used for ballast, fire or general service duties of an intermittent nature, but they are to be immediately available for bilge duty when required. For use of bilge pumps for fire-extinguishing duties, *see* Pt 6, Ch 3,4.

6.3 Capacity of pumps

6.3.1 The capacity of each bilge pump is to be not less than required by the following formula:

$$Q = \frac{5,75}{10^3} d_m{}^2$$

where

Q = capacity, in m^3/h

d_m = Rule internal diameter of main bilge line, in mm, as per 3.2.12, 5.1.1 or 5.4.1 as applicable.

6.3.2 For open hatch dry cargo vessels, the capacity of each bilge pump unit, based on heavy rainfall, should be not less than required by the following formula:

$$Q = \frac{q\, C_h\, B_h}{1600} \text{ m}^3/\text{h}$$

where

q = rainfall mm/h, as applicable for the geographical area in which the ship will operate with a minimum of 25 mm/h but not required to exceed 100 mm/h

C_h = length of the hold, in metres

B_h = breadth of the hold, in metres

The greater capacity as calculated by 6.3.1 or 6.3.2 will be applicable.

6.3.3 In ships other than passenger ships and ships not provided with submersible bilge pumps, where one bilge pump is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other pump. In general, this deficiency is to be limited to 30 per cent.

6.4 Self-priming pumps

6.4.1 All power pumps which are essential for bilge services are to be of the self-priming type.

6.5 Pump connections

6.5.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

6.5.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

6.6 Submersible bilge pump arrangements

6.6.1 Arrangements are to be such that at least two automatic non-return devices are to be fitted between the overboard discharge and the watertight space being served by the pump.

6.6.2 One of these devices is to be fitted at or near the shell as high as practicable but in any case well above the loaded waterline, and the other one may be situated in the pipe work to the pump.

■ *Section 7*
Pipe systems and their fittings

7.1 Prevention of communication between compartments

7.1.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the waterway or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge valve distribution chests.
- Bilge suction hose connections, whether fitted direct to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to the main bilge line.

7.2 Isolation of bilge system

7.2.1 Bilge pipes which are required for draining cargo or machinery spaces are to be entirely distinct from water inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried.

7.3 Machinery space suctions – Mud boxes

7.3.1 Suctions for bilge drainage in machinery spaces are so far as practicable to be led from easily accessible mud boxes with straight tail pipes to the bilges and having covers secured in such a manner as to permit their being expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes.

7.3.2 Where compliance with 7.3.1 is not practicable, strum boxes as described in 7.4.1 are to be fitted to the bilge suctions in the machinery space.

7.4 Hold suctions – Strum boxes

7.4.1 The open ends of bilge suctions in holds and other compartments outside machinery spaces are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

7.5 Tail pipes

7.5.1 The distance between the foot of all bilge tail pipes and the bottom of the bilge is to be adequate to allow a full flow of water and to facilitate cleaning.

7.6 Location of fittings

7.6.1 Bilge valves, cocks and mud boxes are to be fitted at, or above, the machinery space platforms. Where this is not practicable, they may be situated just below the platform, provided readily removable traps or covers are fitted, and nameplates indicate the presence of these fittings.

7.7 Bilge pipes in way of double bottom tanks

7.7.1 Bilge suction pipes are not to be led through double bottom tanks if it is possible to avoid doing so.

7.7.2 Bilge pipes which have to pass through these tanks are to have a wall thickness in accordance with Table 10.2.3 in Chapter 10. The thickness of pipes made from material other than steel will be specially considered.

7.7.3 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the pipes are to be tested, after installation, to the same pressure as the tanks through which they pass.

7.8 Bilge pipes in way of deep tanks

7.8.1 In way of deep tanks, bilge pipes should preferably be led through pipe tunnels but, where this is not done, the pipes are to be of steel, having a wall thickness in accordance with Table 10.2.3 in Chapter 10, with welded joints or heavy flanged joints. The number of joints is to be kept to a minimum.

7.8.2 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the open ends of the bilge suction pipes in the holds are to be fitted with non-return valves of the special type approved for use in holds, *see* 7.9.1.

7.8.3 The pipes are to be tested, after installation, to a pressure not less than the maximum head to which the tanks can be subjected in service.

7.9 Hold bilge non-return valves

7.9.1 Where non-return valves are fitted to the open ends of bilge suction pipes in cargo holds in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

Section 8
Additional requirements for bilge drainage of passenger ships

8.1 Location of bilge pumps and bilge main

8.1.1 In passenger ships, the power bilge pumps required by 6.1.4 and 6.1.5, are to be placed in separate watertight compartments which will not readily be flooded by the same damage. If the engines are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as is possible.

8.1.2 In passenger ships, the arrangements are to be such that at least one power pump will be available for use in all ordinary circumstances in which the ship may be flooded. This requirement will be satisfied if:

- one of the pumps is an emergency pump of a submersible type having a source of power situated above the bulkhead deck; or
- the pumps and their sources of power are so disposed throughout the length of the ship that, under any conditions of flooding which the ship is required to withstand by Statutory Regulations at least one pump in an undamaged compartment will be available.

8.1.3 The bilge main is to be so arranged that no part is situated nearer the side of the ship than $\frac{B}{5}$, measured at right angles to the centreline at the level of the deepest load line,

where

B is the breadth of the ship.

8.1.4 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the line $\frac{B}{5}$, then a non-return valve is to be provided in the pipe connection at the junction with the bilge main. The emergency bilge pump and its connections to the bilge main are to be so arranged that they are situated inboard of the line $\frac{B}{5}$.

8.2 Prevention of communication between compartments in the event of damage

8.2.1 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded, in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the ship than $\frac{B}{5}$ or less than 0,5 m above the bottom, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

8.3 Arrangement and control of bilge valves

8.3.1 All the distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative in any compartment.

8.3.2 If there is only one system of pipes common to all pumps, the necessary valves or cocks for controlling the bilge suctions must be capable of being operated from above the bulkhead deck.

8.3.3 Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions; in this case, only the valves and cocks necessary for the operation of the emergency system need to be capable of being operated from above the bulkhead deck.

8.3.4 All valves and cocks mentioned in 8.3.2 and 8.3.3 which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

Section 9
Drainage arrangements for ships not fitted with propelling machinery

9.1 Hand pumps

9.1.1 Where auxiliary power is not provided, hand pumps are to be fitted, in number and position, as may be required for the efficient drainage of the ship.

9.1.2 The pumps are to be capable of being worked from the upper deck or from positions above the load waterline which are at all times readily accessible. The suction lift is to be well within the capacity of the pump.

9.1.3 The pump capacity is to be based upon the diameter of the suction pipe as determined by the formula in 5.2.1, or 40 mm, whichever is greater.

Section 10
Air and sounding pipes

10.1 Definitions

10.1.1 Reference to cargo oil in this Section is to be taken to mean cargo oil which has a flash point of 55°C or above (closed cup test).

10.2 Materials

10.2.1 Air and sounding pipes are to be made of steel or other approved material. For use of plastics pipes of approved type, *see* Chapter 10.

10.3 Nameplates

10.3.1 Nameplates are to be affixed to the upper ends of all air and sounding pipes.

10.4 Air pipes

10.4.1 Air pipes are to be fitted to all tanks and other compartments (except the void space mentioned in 3.1.4). which are not fitted with alternative ventilation arrangements.

10.4.2 The air pipes are to be fitted at the opposite end of the tank to that which the filling pipes are placed and/or at the highest part of the tank. Where the tank top is of unusual or irregular profile, special consideration will be given to the number and position of the air pipes.

10.4.3 Air pipes are to be arranged to be self-draining under normal conditions of trim.

10.4.4 Air pipes passing through cargo holds are to be of substantial thickness and well protected against mechanical damage.

10.5 Termination of air pipes

10.5.1 Air pipes to double bottom tanks, deep tanks extending to the shell plating, or tanks which can be run up from the waterway are to be led to above the deck. Air pipes to oil fuel and cargo oil tanks, cofferdams and all tanks which can be pumped up are to be led to the open. For height of air pipes above deck, *see* Pt 3, Ch 11,10.

10.5.2 Air pipes from storage tanks containing lubricating or hydraulic oil may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

10.5.3 The open ends of air pipes to oil fuel and cargo oil tanks are to be situated where no danger will be incurred from issuing oil or vapour when the tank is being filled.

10.5.4 The location and arrangement of air pipes for oil fuel service, settling and lubricating oil tanks are to be such that in the event of a broken vent pipe, this does not directly lead to the risk of ingress of outboard water or rainwater.

10.6 Gauze diaphragms

10.6.1 The open ends of air pipes to oil fuel and cargo oil tanks are to be furnished with a wire gauze diaphragm of incorrodible material which can be readily removed for cleaning or renewal.

10.6.2 Where wire gauze diaphragms are fitted at air pipe openings, the area of the opening through the gauze is to be not less than the cross-sectional area required for the pipe, *see* 10.8.

10.7 Air pipe closing appliances

10.7.1 Air pipe closing devices are to be of a type acceptable to Lloyd's Register. If of an automatic opening type they are to be tested in accordance with a National or International Standard recognized by LR.

10.7.2 Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.

10.7.3 For closing requirements, *see also* Pt 3, Ch 11,10.3.

10.8 Size of air pipes

10.8.1 For every tank which can be filled by the ship's pumps, the total cross-sectional area of the air pipes and the design of the air pipe closing devices is to be such that when the tank is overflowing at the maximum pumping capacity available for the tank, it will not be subjected to a pressure greater than that for which it is designed.

10.8.2 In all cases, whether a tank is filled by ship's pumps or other means, the total cross-sectional area of the air pipes is to be not less than 25 per cent greater than the effective area of the respective filling pipe.

10.8.3 Air pipes are to be not less than 40 mm bore. In the case of small gravity filled tanks smaller bore pipes may be accepted but in no case is the bore to be less than 25 mm.

10.9 Overflow sight glasses

10.9.1 Where overflow sight glasses are provided, they are to be in a vertically dropping line and designed such that the oil does not impinge on the glass. The glass is to be of heat resisting quality, adequately protected from mechanical damage and well lit.

10.10 Sounding arrangements

10.10.1 Provision is to be made for sounding all tanks and the bilges of those compartments which are not at all times readily accessible (except the void spaces mentioned in 3.1.4). The soundings are to be taken as near the suction pipes as practicable.

10.10.2 Where fitted, sounding pipes are to be as straight as practicable, and if curved to suit the structure of the ship, the curvature must be sufficiently easy to permit the ready passage of the sounding rod or chain.

10.10.3 Sounding devices of approved type may be used in lieu of sounding pipes for sounding tanks. These devices are to be tested, after fitting on board, to the satisfaction of the Surveyor.

10.10.4 Where gauge glasses are used for indicating the level of liquid in tanks containing lubricating oil, oil fuel or other flammable liquid, the glasses are to be of the flat type of heat-resisting quality, adequately protected from mechanical damage, and fitted with self-closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.

10.11 Termination of sounding pipes

10.11.1 Except as permitted by 10.12 sounding pipes are to be led to positions above the bulkhead deck which are at all times accessible, and in the case of oil fuel tanks, cargo oil tanks, lubricating oil tanks and tanks containing flammable oils, the sounding pipes are to be led to safe positions on the open deck.

10.11.2 For closing requirements, *see also* Pt 3, Ch 11,10.

10.12 Short sounding pipes

10.12.1 In machinery spaces where it is not practicable to extend the sounding pipes as mentioned in 10.11, short sounding pipes extending to well lighted readily accessible positions above the platform may be fitted to double bottom tanks. Any proposal to terminate in the machinery space, sounding pipes to tanks, other than double bottom tanks, will be the subject of special consideration.

10.12.2 Short sounding pipes to oil fuel, (flash point not less than 55°C), lubricating oil tanks and other flammable oil tanks (flash point not less than 55ºC) are to be fitted with cocks having parallel plugs with permanently attached handles, loaded such that, on being released, they automatically close the cocks. In addition, a small diameter self-closing test cock is to be fitted below the cock mentioned above, in order to ensure that the sounding pipe is not under a pressure of oil before opening-up the sounding cock. Provision is to be made to ensure that discharge of oil through this test cock does not present an ignition hazard. An additional small diameter self-closing test cock is not required for lubricating oil tanks.

10.12.3 As a further precaution against fire, such sounding pipes are to be located in positions as far removed as possible from any heated surface or electrical equipment and, where necessary, effective shielding is to be provided in way of such surfaces and/or equipment.

10.12.4 In passenger ships, short sounding pipes are permissible only for sounding cofferdams and double bottom tanks situated in a machinery space, and are in all cases to be fitted with self-closing cocks as described in 10.12.2.

10.13 Striking plates

10.13.1 Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes.

10.13.2 Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

10.14 Sizes of sounding pipes

10.14.1 Sounding pipes are to be not less than 32 mm bore.

■ *Cross-references*

For ventilating and gauging equipment for cargo tanks in oil and chemical tankers, *see* Chapter 13, Sections 4 and 5.
For control engineering equipment, *see* Pt 6, Ch 1.
For requirements relating to scuppers and sanitary discharges, *see* Pt 3, Ch 11.

■ *Section 1* General requirements

1.1 General

1.1.1 In addition to the requirements detailed in this Chapter, the requirements of Ch 11, 1 and 2 are to be complied with, where applicable.

1.1.2 The requirements of Ch 11,3 are also to be complied with, so far as they are applicable, for the drainage of tanks, oily bilges and cofferdams, etc.

1.1.3 The requirements of Sections 2 and 4 are to be complied with, as far as they are applicable, for all flammable liquids.

■ *Section 2* Oil fuel – General requirements

2.1 Flash point

2.1.1 The flash point (closed cup test) is to be not less than 55°C unless specially approved.

2.1.2 Fuels with flash points lower than 55°C may be used in ships intended for service restricted to geographical limits where it can be ensured that the temperature of the machinery spaces will always be 10°C below the flash point of the fuel. In such cases, safety precautions and the arrangements for storage and pumping will be specially considered. However, the flash point of the fuel is to be not less than 43°C unless specially approved.

2.2 Ventilation

2.2.1 The spaces in which the oil fuel burning appliances and the oil fuel settling and service tanks are fitted are to be well ventilated and easy of access.

2.3 Boiler and thermal oil heater insulation and air circulation

2.3.1 The boilers and thermal oil heaters are to be suitably lagged. The clearance spaces between the boilers or heaters and the sides of storage tanks in which oil fuel and cargo oil is carried, are to be adequate for the free circulation of the air necessary to keep the temperature of the stored oil sufficiently below its flash point.

2.4 Heating arrangements

2.4.1 Where steam is used for heating oil fuel, cargo oil or lubricating oil, in bunkers, tanks, heaters or separators, the exhaust drains are to discharge the condensate into an observation tank in a well lighted and accessible position where it can be readily seen whether or not it is free from oil, *see* Ch 13,6.4.

2.4.2 Where hot water is used for heating, means are to be provided for detecting the presence of oil in the return lines from the heating coils.

2.4.3 For requirements of thermal oil systems as heating medium, *see* Section 11 and Ch 13,6.

2.4.4 The steam heating pipes in contact with oil are to be of iron, steel, approved aluminium alloy or approved copper alloy, and after being fitted on board, are to be tested by hydraulic pressure in accordance with the requirements of Ch 10,9.2.

2.4.5 Where electric heating elements are fitted, means are to be provided to ensure that all elements are submerged at all times when electric current is flowing and that their surface temperature cannot exceed 220°C.

2.4.6 For requirements of heating cargo tanks, *see* Ch 13,6.

2.5 Temperature indication

2.5.1 Tanks and heaters in which oil is heated are to be provided with suitable means for ascertaining the temperature of the oil.

2.5.2 Where thermometers or temperature sensing devices are not fitted in blind pockets, a warning notice, in raised letters, is to be affixed adjacent to the fittings stating 'Do not remove unless tank/heater is drained'.

2.5.3 Controls are to be fitted to limit oil temperatures in oil storage and service tanks and in oil heaters to the maximum approved operating temperature, *see* Pt 6, Ch 1.

2.6 Precautions against fire

2.6.1 Settling and daily service oil fuel tanks and oil fuel filters are not to be situated immediately above boilers or other highly heated surfaces. *See also* Ch 1,4.4.

2.6.2 Oil fuel pipes are not to be installed above or near high temperature equipment. Oil fuel pipes should also be installed, and screened or otherwise suitably protected, to avoid oil spray or oil leakages onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. Pipe joints are to be kept to a minimum, and, where provided, are to be of a type acceptable to Lloyd's Register (hereinafter referred to as LR). Pipes are to be led in well lighted and readily visible positions. *See also* Ch 2,7.

2.6.3 Pumps, filters, strainers and heaters are to be located to avoid oil spray or oil leakages onto hot surfaces or other sources of ignition, or onto rotating machinery parts. Where necessary, shielding is to be provided and the arrangements are to allow easy access for routine maintenance. The design of filters and strainers is to be such that they cannot be opened when under pressure and suitable means for pressure release are to be provided, with drain pipes led to a safe location.

2.6.4 The arrangement and location of short sounding pipes to oil tanks are to be in accordance with Ch 11,10.12. For alternative sounding arrangements, *see* Ch 11,10.10.

2.6.5 So far as is practicable, the use of wood is to be avoided in the machinery spaces of ships burning oil fuel.

2.6.6 Drip trays are to be fitted under all oil fuel appliances which are required to be opened up frequently for cleaning or adjustment.

2.6.7 Oil-tight drip trays of ample size having suitable drainage arrangements should be provided at pipes, pumps, valves and other fittings where there is a possibility of leakage. Valves should be located in well lighted and readily visible positions. Drip trays will not be required where pumps, valves and other fittings are placed in special compartments either inside or outside the machinery space with approved overall drainage arrangements, *see* 2.6.2.

2.6.8 Where drainage arrangements are provided from collected leakages, they are to be led to a suitable oil drain tank not forming part of an overflow system.

2.6.9 Separate oil fuel tanks are to be placed in an oil-tight spill tray of ample size having drainage arrangements leading to a drain tank of suitable size, *see* 4.10.

■ *Section 3*
Oil fuel burning arrangements

3.1 Oil fuel supply to main and auxiliary engines

3.1.1 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary engines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the engines.

3.2 Burner arrangements

3.2.1 The burner arrangements are to be such that a burner cannot be withdrawn unless the oil fuel supply to that burner is shut-off, and that the oil cannot be turned on unless the burner has been correctly coupled to the supply line.

3.3 Quick-closing valve

3.3.1 A quick-closing master valve is to be fitted to the oil supply to each thermal oil heater or boiler manifold, suitably located so that the valve can be readily operated in an emergency, either directly or by means of remote control, having regard to the machinery arrangements and location of controls.

■ *Section 4*
Oil fuel pumps, pipes, fittings, tanks, etc.

4.1 Control of pumps

4.1.1 The power supply to all independently driven oil fuel transfer and pressure pumps is to be capable of being stopped from a position outside the space which will always be accessible in the event of fire occurring in the compartment in which they are situated, as well as from the compartment itself.

4.2 Relief valves on pumps

4.2.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in close circuit, i.e. arranged to discharge back to the suction side of the pump and to effectively limit the pump discharge pressure to the design pressure of the system.

4.3 Pump connections

4.3.1 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

4.4 Pipes conveying oil

4.4.1 Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are to be made of steel, having flanged or other approved joints suitable for a working pressure of not less than 7 bar. The flanges are to be machined and the jointing material is to be impervious to oil. Where the pipes are 25 mm bore or less, they may be of seamless copper or copper alloy, except those which pass through oil storage tanks. Oil pipes within the machinery spaces are to be fitted where they can be readily inspected and repaired.

4.4.2 Pipes conveying oil under pressure are to be of seamless steel or other approved material having flanged or welded joints suitable for a working pressure of not less than 16 bar, are to be placed in sight above the platform in well lighted and readily accessible parts of the machinery spaces. The number of flanged joints are to be kept to a minimum.

4.4.3 Where pipes convey heated oil under pressure, the flanges are to be machined, and the jointing material, which is to be impervious to oil heated to 150 °C, is to be the thinnest possible, so that the flanges are practically metal to metal. The scantlings of the pipes and their flanges are to be suitable for a pressure of at least 14 bar or for the design pressure, whichever is the greater.

4.4.4 For requirements regarding bilge pipes in way of double bottom tanks and deep tanks, *see* Ch 11,7.7 and 7.8.

4.5 Valves and cocks

4.5.1 Valves, cocks and their pipe connections are to be so arranged that oil cannot be admitted into tanks which are not structurally suitable for the carriage of oil or into tanks which can be used for the carriage of fresh water.

4.5.2 All valves and cocks forming part of the oil fuel installation are to be capable of being controlled from readily accessible positions which, in the machinery spaces, are to be above the working platform. *See also* Ch 11,2.3.

4.5.3 Every oil fuel suction pipe from a double bottom tank is to be fitted with a valve or cock.

4.6 Valves on tanks and their control arrangements

4.6.1 Every oil fuel suction pipe from a storage, settling and daily service tank and every oil fuel levelling pipe within the machinery spaces is to be fitted with a valve or cock secured to the tank.

4.6.2 The valves and cocks mentioned in 4.6.1 are to be capable of being closed locally and from positions outside the space in which the tank is located. The remote controls are to be accessible in the event of fire occurring in these spaces. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

4.6.3 In the case of tanks of less than 500 litres capacity, consideration will be given to the omission of remote controls.

4.6.4 Where the filling pipes to oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in 4.6.2.

4.7 Water drainage from settling tanks

4.7.1 Settling tanks are to be provided with means of draining water from the bottom of the tanks.

4.7.2 If settling tanks are not provided, the oil fuel bunkers or daily service tanks are to be fitted with water drains.

4.7.3 Open drains for removing water from oil tanks are to be fitted with valves or cocks of self-closing type, and suitable provision is to be made for collecting the oily discharge.

4.8 Separation of cargo oils from oil fuel

4.8.1 Pipes conveying vegetable oils, edible oils or similar cargo oils are not to be led through oil fuel tanks, nor are oil fuel pipes to be led through tanks containing these cargo oils. For requirements regarding provision of cofferdams between oil and water tanks, *see* Pt 3, Ch 3.

4.9 Fresh water piping

4.9.1 Pipes in connection with compartments used for storing fresh water are to be separate and distinct from any pipes which may be used for oil or oily water, and are not to be led through tanks which contain oil, nor are oil pipes to be led through fresh water tanks.

4.10 Separate oil fuel tanks

4.10.1 For rectangular steel tanks of welded construction, the plate thicknesses are to be not less than those indicated in Table 12.4.1, and not less than 3 mm. The stiffeners are to be of approved dimensions.

4.10.2 The dimension given in Table 12.4.1 for the breadth of the panel is the maximum distance allowable between continuous lines of support, which may be stiffeners, wash-plates or the boundary of the tank.

4.10.3 On completion, the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

4.10.4 The dimension given in Table 12.4.1 for the breadth of the panel is the maximum distance allowable between continuous lines of support, which may be stiffeners, wash-plates or the boundary of the tank.

Table 12.4.1 Plate thickness of separate oil fuel tanks

Thickness of plate, in mm	Head from bottom of tank to top of overflow pipe, in metres				
	2,5	3,0	3,5	4,0	4,5
	Breadth of panel, in mm				
3	315	290	—	—	—
4	475	435	400	375	350
5	630	575	535	500	470
6	790	720	670	625	590
7	950	865	800	750	710
8	1105	1010	935	875	825

4.10.5 Valves are to be attached direct to the tank plating. These fittings are to be secured by studs screwed into heavy steel pads welded to the plating. Alternatively, a short rigid pipe stub, welded into the shell plating and provided with a flange, may be used.

4.10.6 Threaded connections below the oil level may be used up to and including NB 25, provided tapered threads will be used. Alternatively, threaded connections with parallel threads, intended for instrumentation connections, are to be provided with a collar and a facing around the hole in order to provide a joint face.

■ *Section 5*
Steam piping systems

5.1 Provision for expansion

5.1.1 In all steam piping systems, provision is to be made for expansion and contraction to take place without unduly straining the pipes.

5.1.2 Where expansion pieces are used, particulars are to be submitted.

5.1.3 For installation requirements regarding expansion pieces, *see* Ch 11,2.7.

5.2 Drainage

5.2.1 The slope of the pipes and the number and position of the drain valves or cocks are to be such that water can be efficiently drained from any position of the steam piping system.

5.2.2 Arrangements are to be made for ready access to the drain valves or cocks.

5.3 Pipes in way of holds

5.3.1 In general, steam pipes are not to be led through spaces which may be used for cargo, but where it is impracticable to avoid this arrangement, plans are to be submitted for consideration. The pipes are to be efficiently secured and insulated, and well protected from mechanical damage. Pipe joints are to be as few as practicable and preferably butt welded.

5.4 Pipes in dangerous area of tankers

5.4.1 The surface temperature of the steam pipes fitted on deck or in the pump room of tankers is not to exceed 220°C.

5.5 Reduced pressure lines

5.5.1 Pipelines which are situated on the low pressure side of reducing valves, and which are not designed to withstand the full pressure at the source of supply, are to be fitted with pressure gauges and with relief valves having sufficient discharge capacity to protect the piping against excessive pressure.

■ *Section 6*
Boiler feed water systems

6.1 General

6.1.1 In view of the limited use of steam on ships for Inland Waterways, feed water systems will be considered in accordance with Pt 5, Ch 14,6 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) as far as they are applicable.

■ *Section 7*
Engine cooling water systems

7.1 Cooling water supply

7.1.1 Provision is to be made for an adequate supply of cooling water to the main propelling machinery and essential auxiliary engines, also the lubricating oil and fresh water coolers, where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

7.2 Relief valves on main cooling water pumps

7.2.1 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge to effectively limit the pump discharge pressure to the design pressure of the system.

7.3 Water inlets

7.3.1 Not less than two water inlets are to be provided for the pumps supplying the cooling water system.

7.3.2 Cooling water pump inlets are to be low inlets.

7.4 Strainers

7.4.1 Where outboard water is used for the direct cooling of the main engines and essential auxiliary engines, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

7.5 Box coolers

7.5.1 Box coolers with the top of the inlet chest less than 400 mm above the waterline shall not be dismounted when the ship is afloat. A legible name plate is to be fitted in a prominent position to that effect.

7.5.2 Box coolers with the top of the inlet chest exceeding 400 mm may be dismounted when the ship is afloat with permission of the skipper. A legible name plate is to be fitted in a prominent position to that effect.

7.5.3 Box cooler chests are to be provided with a suitable de-aeration pipe of extra heavy gauge with an approved shipside valve. The pipe is to be led to above the waterline.

■ *Cross-references*

For guidance on metal pipes for water services, *see* Ch 10,10.

■ *Section 8*
Lubricating oil systems

8.1 General

8.1.1 In addition to the requirements detailed in this Section, the requirements of Sections 2 and 4 are to be complied with in so far as they are applicable. In all cases, the following are to apply:
- 2.6.1 to 2.6.3, Precautions against fire.
- 4.1, Control of pumps.
- 4.2, Relief valves on pumps.
- 4.4, Pipes conveying oil.
- 4.10, Separate oil fuel tanks.

8.1.2 Satisfactory lubrication of the engines is to be ensured while starting and manouvring.

8.1.3 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

8.2 Alarms

8.2.1 All main and auxiliary engines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines are of more than 37 kW, audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. These alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

8.3 Filters

8.3.1 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing the supply of oil to the engine.

8.4 Cleanliness of pipes and fittings

8.4.1 Extreme care is to be taken to ensure that lubricating oil pipes and fittings, before installation, are free from scale, sand, metal particles and other foreign matter.

8.5 Lubricating oil contamination

8.5.1 The materials used in the storage and distribution of lubricating oil are to be selected such that they do not introduce contaminants or modify the properties of the oil. The use of cadmium or zinc in lubricating oil systems where they may normally come into contact with the oil is not permitted.

8.5.2 The design and construction of engine and gear box piping arrangements are to prevent as far as practicable, contamination of engine lubricating oil systems by leakage of cooling water or from bilge water where engines or gearboxes are partly installed below the lower platform.

8.5.3 Where a lubricating oil filling pipe and cap are provided for engines or other machinery, provision is to be made for the topping up oil to safely pass through a suitable strainer. The caps are to be capable of being secured in the closed position.

■ *Section 9*
Hydraulic systems

9.1 General

9.1.1 The arrangements for storage, distribution and utilisation of hydraulic and other flammable oils employed under pressure in power transmission systems, control and actuating systems in locations where means of ignition are present, are to comply with the provisions of:

- 2.6.1 to 2.6.3, Precautions against fire.
- 4.1, Control of pumps.
- 4.2, Relief valves on pumps.
- 4.4, Pipes conveying oil.
- 4.10, Separate oil fuel tanks.

9.2 System arrangements

9.2.1 Hydraulic fluids are to be suitable for the intended purpose under all operating service conditions.

9.2.2 Materials used for all parts of hydraulic seals are to be compatible with the working fluid at the appropriate working temperature and pressure.

9.2.3 Over-pressure protection is to be provided on the discharge side of all pumps. Where relief valves are fitted for this purpose, they are to be fitted in closed circuit, i.e. arranged to discharge back to the system oil tank.

9.2.4 Provision is to be made for hand operation of the systems in an emergency, unless an acceptable alternative is available.

9.2.5 Where hydraulic securing arrangements are applied, the system is to be capable of being locked in the closed position, so that in the event of hydraulic system failure, the securing arrangements will remain locked.

9.2.6 Where pilot operated non-return valves are fitted to hydraulic cylinders for locking purposes, the valves are to be connected directly to the actuating cylinder(s) without intermediate pipes or hoses.

9.2.7 For requirements relating to hydraulic steering gear arrangements, *see* Ch 15,3.

9.2.8 For requirements relating to hydraulic systems for liftable wheelhouses, *see* Ch 18,2 and 3.

9.2.9 Suitable oil collecting arrangements for leaks shall be fitted below hydraulic valves and cylinders.

■ *Section 10*
Low pressure compressed air systems

10. General

10.1.1 The requirements of this Section are applicable to low pressure (LP) compressed air systems which are essential for pneumatic control and instrumentation purposes.

10.2 Compressors

10.2.1 Air compressors are in general to comply with the requirements of Ch 2,8.

10.3 Air receivers

10.3.1 All air receivers are to comply with the requirements of Chapter 9, as applicable.

10.3.2 Stop valves on air receivers are to permit slow opening to avoid sudden pressure rises in the piping system.

10.4 Distribution system

10.4.1 Pipelines that are situated on the low pressure side of reducing valves/stations and that are not designed to withstand the full pressure of the source supply, are to be provided with pressure gauges and relief valves, having sufficient capacity to protect the piping against excessive pressure.

10.5 Pneumatic remote control valves

10.5.1 Where valves, which are required by the Rules to be capable of being closed from outside a machinery space, have pneumatic closing arrangements, a dedicated air receiver is to be fitted to supply compressed air to the valves. This air receiver is to be located outside the machinery space.

10.5.2 The air receiver is to be maintained fully charged from the main LP air system via a non-return valve located at the air receiver inlet which is to be locked in the open position.

10.5.3 In the case of passenger ships, a permanently attached hand-operated air compressor capable of charging the air receiver is to be provided in the space in which the air receiver is located.

10.5.4 The capacity of the air receiver is to be sufficient to operate all valves and any other essential supplies such as ventilation flaps without replenishment.

10.5.6 The pneumatic pilot pipes running through the machinery space to the relevant control mechanism of the valves are to be of steel.

10.6 Control arrangements

10.6.1 The control, alarm and monitoring systems are to comply with Pt 6, Ch 1.

■ *Section 11* Thermal oil systems

11.1 General

11.1.1 The requirements of this Section are applicable to thermal oil systems heated by oil fired appliances intended for heating of cargo.

11.1.2 Exhaust gas heating arrangements and heating arrangements intended for own propulsion will be specially considered.

11.1.3 The arrangements for storage, distribution and utilisation of thermal oil under pressure are to comply with the requirements detailed in this Section. The requirements of Sections 1, 2, 3 and 4 are to be complied with in so far as they are applicable. In all cases, the following are to apply:

- 2.6.1 to 2.6.3, Precautions against fire.
- 4.1, Control of pumps.
- 4.2, Relief valves on pumps.
- 4.4, Pipes conveying oil.
- 4.6, Valves on tanks and their control arrangements.

11.1.4 An approved type of thermal oil is to be used. The proposed thermal oil should be stated, giving flash point (>55°C), fire point, auto-ignition temperature and maximum operating temperature.

11.2 Piping

11.2.1 Joints in thermal oil systems are preferably to be of welded construction, where used the number of flanged joints is to be kept to a minimum.

11.2.2 Expansion joints of an approved type or bends are to be provided, where necessary, in the thermal oil pipe lines. Moreover, the thermal oil pipes are to be suitably supported and anchored.

11.2.3 All air release pipes in the system should be fitted with self-closing cocks and led to the expansion tank.

11.2.4 Suitable strainers should be fitted on the suction side of the circulating pumps to filter out any carbonised oil.

11.2.5 Copper and copper alloys are suspect able for catalytic action with thermal oil and should not be used.

11.2.6 Thermal oil pipes are not to be led through accommodation or service spaces. For service spaces situated inside the dangerous zone of tankers, *see* Ch 13,1.9.4.

11.2.7 Hydraulic tests and non-destructive examination on pipes and fittings are to comply with Ch 10,9 and Ch 14,7 respectively, as applicable.

11.2.8 Pipe penetrations through bulkheads or decks outside the cargo area are to be insulated.

11.3 Expansion tank arrangement

11.3.1 A positive pressure in the heating coils exceeding the external pressure is to be maintained under all conditions of service irrespective of the type of cargo to be carried. This can be achieved by means of an atmospheric expansion tank situated at sufficient height or by pressurising the expansion tank with an inert gas or compressed air. Arrangements for atmospheric expansion tanks are to comply with 11.3.3 to 11.3.5 and arrangements for pressurized expansion tanks are to comply with 11.3.6 to 11.3.9.

11.3.2 For the minimum required pressure in the expansion tank or, alternatively, the minimum required height above the installation, *see* Ch 13,6.4.9.

11.3.3 Means of approved type are to be provided to ascertain the level in the thermal expansion tank.

11.3.4 The expansion/header tank is to be fitted with both high and low level alarms. At low level alarm, the circulation pump is to be stopped automatically and the thermal oil heater is to be shut down.

11.3.5 The vent pipe from the expansion tank is to be led to a safe position on the open deck.

11.3.6 For expansion tanks provided with an inert gas padding, it is to be guaranteed that sufficient inert gas will be available to maintain the pressure in the expansion vessel under all conditions of service.

11.3.7 For expansion tanks pressurised by compressed air, it is to be guaranteed that the temperature of the thermal oil in the expansion tank is not to exceed 50°C in order to avoid oxidation of the thermal oil.

11.3.8 The expansion vessel is to be provided with a pressure indication and alarm for the minimum pressure. At low pressure alarm, the circulation pump is to be stopped automatically and the thermal oil boiler is to be shut down.

11.3.9 A pressurized expansion vessel is to be protected against over pressure by a relief valve, the discharge of which is to be led to a safe position on the open deck.

11.3.10 As an alternative to the quick closing valve as per 11.1.3, a quick drainage arrangement can be installed as per 11.3.11 to 11.3.13.

11.3.11 The expansion tank is to be provided with an quick opening valve remotely controlled from outside the space in which the expansion tank is situated.

11.3.12 The thermal oil dump tank shall have sufficient capacity to accumulate the contents of the expansion tank.

11.3.13 Actuating of the quick opening valve is to initiate stopping of the circulating pump(s) and shut down of the thermal oil heater.

11.4 Thermal oil heater arrangements

11.4.1 Alarms and safeguards are to be fitted in accordance with Pt 6, Ch 1.

11.4.2 A thermostatic control or cut-out actuated by the circulating thermal oil temperature, failure of the circulating thermal oil pumps and 'flame out', is to be incorporated in the oil fired thermal oil heater burner system.

11.4.3 The oil fired thermal oil heater is to be fitted with temperature sensors and alarms for fire detection.

■ *Cross-references*

For air and sounding pipes and gauge glasses, *see* Ch 11,10. For separation of lubricating oil tanks from fuel tanks, *see* Pt 3, Ch 3. For thermal oil system requirements for oil and chemical tankers, *see* Ch 13,6.

Piping Systems for Ships Intended for the Carriage of Liquids in Bulk

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are additional to those of Chapter 11 and are applicable to ships which are intended for the carriage of liquids in bulk, being self-propelled with machinery aft or non-propelled (barges) being towed, pushed or carried alongside another ship.

1.1.2 For the classification of dangerous liquids into Classes 2, 3, 6.1, 8 and 9, *see* Pt 4, Ch 6,1.3.

1.1.3 For the significance of tankers Types G, C and N and cargoes that may be carried, *see* Pt 4, Ch 6,1.4 and 6,1.5.

1.1.4 For applications and definitions, *see* Pt 4, Ch 6,1.

1.1.5 The requirements of this Chapter basically take into account the **ADNR** Regulations of the Central Rhine Commission and the European provisions concerning the International Carriage of Dangerous Goods by Inland Waterways **ADN** which assume heavy traffic on relatively narrow waterways through heavily populated areas. ADN is an abbreviation from **A**ccord européen relative au transport international des merchandises **D**angereuses par voie de **N**avigation intérieure. The letter 'R' for ADNR is standing for **R**hine. *See also* Pt 4, Ch 4,1.2.

1.1.6 Although the contents of this Chapter take the ADNR and ADN. Regulations into account, the issue of an ADNR/ADN. Certificate on behalf of the Relevant Authorities requires full compliance with their Regulations.

1.1.7 In addition to the requirements of this Chapter, attention is to be given to any National and International technical and operational requirements of countries where the ship is registered or operating and which are outside the area of ADNR/ADN legislation or classification as defined in these Rules.

1.1.8 In addition to the requirements of this Chapter the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* (hereinafter referred to as the Rules for Ships for Liquefied Gases) are to complied with for Type G tankers as far as they are applicable.

1.2 Plans and particulars

1.2.1 In addition to the plans and particulars required in Chapter 11, the following plans (in diagrammatic form) are to be submitted for consideration:

- Pumping arrangements at the fore and aft ends, and drainage of cofferdams and pump-rooms.
- General arrangements of cargo piping in tanks and on deck.
- General arrangements of cargo tank vents. The plan is to indicate the type and position of the vent outlets and distance from any superstructure, erection, air intake, etc.
- Arrangements of inert gas piping systems, together with full details of inert gas plant, if fitted. *See* Section 8.
- Details of alarms and safety arrangements required by 1.6. *See also* Pt 6, Ch 1.2.
- Pressure drop calculations, *see* 4.3.
- Cargo heating systems, *see* Section 6.
- Water spray systems, *see* 7.2.

1.3 Materials

1.3.1 All materials used in the cargo pumping and piping systems and any other piping systems which may come into contact with the cargo are to be suitable for use with the intended cargoes.

1.3.2 Materials for cargo piping systems are to comply with the requirements of Chapter 10 as follows:
Class II systems for Type G Tankers
Class II systems for Type C Tankers
Class II for Type N Tankers carrying toxic or corrosive media
Class III for all other Type N Tankers.

1.3.3 For cargoes which are highly corrosive, materials may be subject to a special consideration.

1.3.4 Where stainless steel is required or accepted as an alternative to mild steel then it is to be essentially an austenitic type and comply with the appropriate requirements of the *Rules for the Manufacture, Testing and Certification of Materials*. Alternative grades of stainless steel may be accepted provided they comply with National or Proprietary specifications and are suitable for the intended purpose.

1.3.5 Wood, aluminium alloy or plastic materials within the cargo area are in general not acceptable. However, consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules.

1.3.6 Vapour collecting or Vapour return pipe lines are to be suitably protected against corrosion.

1.3.7 A list of Defined Cargoes, intended to be carried on board, is to be established. Due account is to be given to the materials proposed. *See* Pt 4, Ch 4,1.3 for dangerous liquids. *See* Pt 4, Ch 5,1.5 for Type G tankers and Chapter 6,1.5 for Type C and N tankers.

1.3.8 For a list of dangerous goods, *see* the ADNR/ADN, Table C, Part 3. Subject list of chemicals could be downloaded from: http://www.ccr-zkr.org. *See also* Pt 4, Ch 6,1.3.

1.3.9 All additional requirements for the particular substance as contained in Table C of Part 3 of the ADNR/ADN are to be complied with by the particular tanker before a substance is allowed to be carried. This also includes any additional requirements contained in column 20 of Table C.

1.4 Design

1.4.1 All piping, valves and fittings are to be suitable for the maximum pressure to which the system can be subjected.

1.4.2 Piping subjected to pressure is to be of seamless or other approved type, and is to comply with the requirements of Chapter 10. Alternatively, longitudinally welded pipes could be accepted, provided the method of welding is acceptable and the weld will be Non-Destructive Examined in compliance with Ch 14,7.

1.4.3 Joints in cargo piping, outside the cargo tanks, are preferably to be of welded construction. Where used, the number of flanged joints is to be kept to a minimum and the types of flange attachments are to be in accordance with Ch 10,2.

1.4.4 For Type C and N tankers, threaded pipe joints/connections of an approved type are acceptable for NB 25 and smaller. A maximum diameter of 51 mm could be accepted for cargo oil only. *See also* Ch 10,2.10.

1.4.5 For Type G tankers, screwed couplings could be accepted only for accessory lines and instrumentation lines with external diameters of 25 mm or less, provided the couplings are of an approved type.

1.4.6 Loading and discharge pipes, including stripping pipes are to be permanent pipes.

1.5 Cargo zone

1.5.1 For definition of cargo zone, *see* Pt 4, Ch 6,1.1.

1.5.2 Internal combustion engines, or any other equipment which could constitute a possible source of ignition, are not to be situated within the cargo zone, except in the case of Type N-open tankers not built in compliance with ADNR/ADN requirements.

1.5.3 Any air intakes for machinery spaces and engines are to be so arranged that their openings are not less than 2 m outside the cargo zone.

1.5.4 For the requirements for earthing and bonding of pipework for the control of static electricity, *see* Pt 6, Ch 2.

1.5.5 Outlets of exhaust gas lines from engines are to be provided with a device to prevent the discharge of sparks such as spark arrestors. For all tankers, exhaust lines from engines are not to be led through the cargo zone, the distance between their outlets and the cargo zone shall be not less than 2 m and the exhaust gases should be blown out in a direction away from the ship.

1.5.6 For protection against the ingress of gases within accommodations and entrances (i.e. the relevant distances from openings and equipment in the cargo zone and openings and equipment outside the cargo zone) *see* Pt 4, Ch 6,3.3.

1.6 Cargo pump-room

1.6.1 Cargo pump-rooms, if fitted, are to be totally enclosed and have no direct communication with machinery spaces. For bilge drainage arrangements in pump-rooms, *see* 2.2.

1.6.2 For ships required to comply with the ADNR/ADN Regulations, the cargo pump room is to be separated from the engine room or service space outside the cargo zone by a cofferdam, hold space containing cargo tanks or service space. Alternatively, the bulkhead between the machinery space/pump room or service space outside the cargo zone/pump room is to be provided with a fire insulation A-60 in accordance with SOLAS II-2, Reg. 3. This requirement is not applicable for Type N – open tankers. Shaft penetrations for pumps as per 2.2.12 and 3.2.5 are not acceptable for bulkheads having an A-60 insulation.

1.6.3 Pump-rooms are to be situated within the cargo zone and are to be provided with ready means of access from the deck.

1.6.4 Alarms and safety arrangements are to be provided as indicated in 1.6.6, 1.6.7 and Table 13.1.1.

Table 13.1.1 Alarms and safety arrangements

Item	Alarm	Note
Bulkhead gland temperature	High	Any machinery item
Bearing temperature	High	Any machinery item
Pump casing temperature	High	Cargo pumps only
Bilge level	High	
Hydrocarbon concentration	High	> 10% LEL

1.6.5 A system for continuously monitoring the concentration of hydrocarbon gases and oxygen within the cargo pump room is to be fitted. Sampling points are to be located in positions such as in way of the bottom of the pump room and just below the main deck where potentially dangerous concentrations of hydrocarbon gases, or lack of oxygen, may be readily detected. This requirement is not applicable for Type N-open tankers.

1.6.6 Visual and audible alarms for the hydrocarbon concentration as per Table 13.1.1 are to be fitted in the wheelhouse and pump room. At hydrocarbon alarm the gas discharge installation on Type G tankers is to be stopped. For all other tankers the loading or discharging installation is to be stopped.

1.6.7 An optic and acoustic alarm is to be provided in the wheelhouse indicating malfunctioning of the gas detection installation.

1.6.8 All cargo piping, including the stripping pipes for Type C and N tankers, except the N-open type, are to be provided with a valve secured to the bulkhead capable of being operated from an accessible position above the weather deck. *See also* 3.7. Control of the pump capacity is to be arranged also from this position.

1.6.9 All cargo piping (suction and discharge side) for Type G tankers are to pass through the deck above the pump room the necessary control of valves in the pump room and control of the pump capacity is to be arranged from above the weather deck.

1.7 Cargo pump-room ventilation

1.7.1 For all tanker Types, the requirements of 1.7.2 to 1.7.11 are to be complied with. Natural ventilation is acceptable for Type N-open tankers.

1.7.2 Cargo pump-rooms and other enclosed spaces which contain cargo handling equipment, and to which regular access is required during cargo handling operations, are to be provided with permanent ventilation systems of the mechanical extraction type.

1.7.3 The ventilation system is to be capable of being operated from outside the compartment being ventilated, and the following notices are to be fixed near the entrance:

> 'Before entering, pump room is to be tested for gas concentration and sufficient oxygen.'
> and
> 'Doors and access openings are not to be opened without permission of the skipper.'
> and
> 'In the event of alarm, pump room is to be left immediately'.

1.7.4 Before entering the space the ventilation system is to be in operation for at least 30 minutes.

1.7.5 The ventilation system is to start automatically in case of high alarm hydrocarbon concentration.

1.7.6 The ventilation system is to be capable of at least 30 air changes per hour, based on the gross volume of the pump-room.

1.7.7 The ventilation system is to be suitable for operation in a dangerous atmosphere.

1.7.8 The ventilation ducting is to be arranged to permit extraction from the vicinity of the pump-room bilges. Air intakes are to be so arranged in the upper part of the pump-room to minimize the possibility of recycling hazardous vapour from any ventilation discharge opening. Vent exits are to be arranged to discharge upwards.

1.7.9 Renewable flame screens are to be provided in ventilation ducts.

1.7.10 Provision is to be made for closing the air intake and extraction ducts in case of fire. The means provided are to be capable of operation from the deck. This requirement is not applicable for Type N-open tankers.

1.7.11 Ventilation openings are to be arranged at a horizontal distance of not less than 6 m away from accommodation and service spaces outside the cargo zone. This requirement is not applicable for Type N-open tankers.

1.8 Non-sparking fans for hazardous areas

1.8.1 The air gap between impeller and housing of the fan is to be not less than 0,1 of the impeller shaft bearing diameter or 2 mm whichever is the larger, subject also to compliance with 1.8.2(e). Generally, however, the air gap need be no more than 13 mm.

1.8.2 The following combinations of materials are permissible for the impeller and the housing in way of the impeller:

(a) impellers and/or housings of non-metallic material, due regard being paid to the elimination of static electricity;
(b) impellers and housings of non-ferrous metals;
(c) impellers and housings of austenitic stainless steel;
(d) impellers of aluminium alloys or magnesium alloys and a ferrous housing provided that a ring of suitable thickness of non-ferrous material is fitted in way of the impeller;
(e) any combination of ferrous impellers and housings with not less than 13 mm tip clearance;
(f) any combination of materials for the impeller and housing which are demonstrated as being sparkproof by appropriate rubbing tests.

1.8.3 The following combinations of materials for impellers and housings are not considered sparkproof and are not permitted:

(a) impellers of aluminium alloy or magnesium alloy and a ferrous housing irrespective of tip clearance;
(b) impellers of a ferrous material and housings made of an aluminium alloy, irrespective of tip clearance;
(c) any combination of ferrous impeller and housing with less than 13 mm tip clearance, other than permitted by 1.8.2(c).

1.8.4 Electrostatic charges both in the rotating body and the casing are to be prevented by the use of antistatic materials (i.e. materials having an electrical resistance between 5×10^4 ohms and 10^8 ohms), or special means are to be provided to avoid dangerous electrical charges on the surface of the material.

1.8.5 Evidence of satisfactory type testing of the complete fan, witnessed by a recognized Authority or by LR's Surveyors is to be provided.

1.8.6 Protection screens of not more than 13 mm square mesh are to be fitted in the inlet and outlet of ventilation ducts to prevent the entry of objects into the fan housing.

1.8.7 The installation of the ventilation units on board is to be such as to ensure the safe bonding to the hull of the units themselves.

1.8.8 Non-sparking fans are not required for Type N-open tankers.

1.9 Bulkhead penetrations

1.9.1 Penetrations through the bulkhead between the machinery space and the pump room/cofferdam in the cargo area, or the bulkhead between the machinery space and the hold spaces containing cargo tanks may be provided for electrical cables, hydraulic lines and piping for measuring, control and alarm systems, provided that the penetrations are of an approved gastight type.

1.9.2 For ships required to comply with the ADNR/ADN Regulations penetrations through a bulkhead with an 'A-60' fire protection insulation according to SOLAS 74, Chapter II-2, Regulation 3, shall have an equivalent fire protection. *See also* 1.6.2.

1.9.3 Pipes may pass through the bulkhead between the machinery space and the pump room/cofferdam in the cargo area, provided that these pipes are connecting mechanical equipment between the machinery space and the pump room/cofferdam and do not have any openings within the pump room/cofferdam.

1.9.4 Pipes from the machinery space led to the open, may pass through the pump room/cofferdam in the cargo area or a hold space containing the cargo tanks to the open, provided that within the spaces mentioned above they are of seamless steel and of substantial wall thickness and have no flanged joints or openings.

■ *Section 2*
Piping systems for bilge, ballast, oil fuel, etc.

2.1 Pumping arrangements at ends of ship

2.1.1 The pumping arrangements in the machinery space and at the forward end of the ship are to comply with the requirements for general cargo ships, in so far as they are applicable, and with the special requirements detailed in this Section.

2.1.2 Bilge, ballast and oil fuel lines, etc., which are connected to pumps, tanks or compartments at the ends of the ship, are not to pass through cargo tanks or have any connections to cargo tanks.

2.1.3 The oil fuel bunkering system is to be entirely separate from the cargo handling system.

2.2 Drainage and/or ballasting of spaces within the cargo zone

2.2.1 Provision is to be made for the bilge drainage of under deck cargo pump-rooms by pump or bilge ejector suctions. The pump-room bilges of small tankers may be drained by means of a hand pump having a 50 mm bore suction. Pump-room suctions are not to enter machinery spaces. In case of emergency the pump-room is to be drained by a bilge unit situated outside the pump-room and independent of all other installations in the cargo zone.

2.2.2 For all tankers, a bilge alarm is to be fitted in under deck pump-rooms which will activate a visual and audible alarm in the wheelhouse to warn that the liquid in the pump room bilge has reached a predetermined level.

2.2.3 Bilge or ballast pumps serving spaces within the cargo zone other than cargo tanks are to be placed in that zone and their piping systems are to be separate from any other piping system. For exemptions, *see* 2.2.10.

2.2.4 For all tankers, arrangements are to be made to fill the cofferdams by means of a pump. The filling is to be carried out within 30 minutes. Provision is to be made to prevent the cofferdams being subjected to a pressure which is in excess of that for which the cofferdams have been constructed.

2.2.5 For ships required to comply with the ADNR/ADN Regulations and provided with an A-60 bulkhead insulation as per 1.6.2, filling of the cofferdam may be waived.

2.2.6 For cofferdams arranged as service space the requirements of 2.2.4 may be waived.

2.2.7 Cofferdams may be drained by a pump situated in the cargo zone. Alternatively, they may be drained by bilge ejectors.

2.2.8 Cofferdams are not to have any direct connections to the cargo tanks or cargo lines.

2.2.9 Cofferdam pipe systems are to be independent from any other pipe system of the ship.

2.2.10 Bilge or ballast pumps serving spaces within the cargo zone other than cargo tanks may be placed only outside that zone under the following conditions:

- All Type of tankers; for wing tanks and double bottom tanks not having a common boundary with the cargo tanks.
- Type G tankers; for cofferdams and hold spaces containing cargo tanks if ballasting will be carried out through a flexible connection with the fire main. Upon completion of the ballast operation, the fire main must be disconnected from the relevant spaces. The cofferdams and hold spaces are to be drained by bilge ejectors.
- Type N and C tankers; for cofferdams, wing tanks, double bottom tanks and hold spaces containing cargo tanks if ballasting will be carried out through a flexible connection with the fire main. Upon completion of the ballast operation, the fire main must be disconnected from the relevant spaces. The cofferdams and hold spaces are to be drained by bilge ejectors.

2.2.11 The shipside connection for ballast pumps placed in the cargo zone is to be situated within that zone but outside the cargo tanks.

2.2.12 Where bilge and ballast pumps are driven by shafting which passes through a pump room bulkhead or deck, gastight glands of an approved type are to be fitted as per 3.2.5. *See also* Table 13.1.1.

2.2.13 Bilge systems for hold spaces containing independent cargo tanks are to comply with 2.2.14 to 2.2.17.

2.2.14 The diameter d_b of the bilge line suction pipe is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter of any suction to be less than 50 mm:

$$d_b = 2{,}0\sqrt{C\,(B + D)} + 25 \text{ mm}$$

where

d_b = internal diameter of branch bilge suction, in mm
C = length of compartment, in metres
B = Breadth of the hold space, in metres
C = Depth of the compartment, in metres.

2.2.15 Calculation of the minimum required bilge capacity is to be in compliance with Ch 11,6.3.

2.2.16 If the volume of the cargo tank exceeds 75 per cent of the total volume of the hold space the bilge capacity may be reduced by 50 per cent.

2.2.17 The minimum required bilge capacity is to be not less than 12,5 m^3/h.

2.3 Air and sounding pipes

2.3.1 Cofferdams are to be provided with not less than two air pipes each in order to obtain a reasonable circulation of air. One of the air pipes is to be led near the bottom of the cofferdam. Sounding pipes on the cofferdam are to be led to the open deck. The air pipes, except for Type N-open Tankers, are to be fitted with a wire gauze diaphragm at their outlets, of an approved type and capable to resist a deflagration.

2.3.2 Double bottom tanks and wing tanks in the cargo area are to be provided with an air pipe as per Ch 11,10. Sounding pipes on the cofferdam are to be led to the open deck.

2.4 Double bottom tanks below cargo tanks and wing tanks

2.4.1 Where double bottom tanks are fitted below cargo tanks and for wing tanks, the requirements of 2.2.7 to 2.2.9 are applicable. For air and sounding pipes *see* 2.3.2.

2.4.2 Double bottom tanks below cargo tanks and wing tanks may be used for ballast purposes only.

2.4.3 For ships having hold spaces containing cargo tanks, double bottom tanks may be used as oil fuel tanks provided:

- the height of the double bottom tank is not less than 0,60 m.
- oil fuel pipes and openings of these tanks are not fitted or terminating in the hold spaces.
- air pipes are led to the open deck with a height of not less than 0,50 m above deck.
- air pipes are fitted with a wire gauge as per Ch 10,6.

■ *Section 3* Cargo handling system

3.1 General

3.1.1 A complete system of piping and pumps is to be fitted for dealing with the cargo.

3.1.2 Arrangements for emptying tanks by means of applying pressure above the cargo or by other methods will be specially considered.

3.1.3 Connections should be made for the gas freeing of the cargo tanks, when the cargo has been discharged, and for the ventilation and gas freeing of all compartments adjacent to cargo tanks.

3.1.4 Where gas freeing arrangements are provided, fans are to be installed in the cargo zone. The fans are to be of non-sparking material except for Type N-open. *See also* 1.8. Where driving motors are electrical and are situated in the cargo zone, they are to be of the certified safe type, *see* Pt 6, Ch 2,13.7. Otherwise the fan prime mover is to be installed outside the hazardous area in an enclosed space. Where the driving shaft penetrates the bulkhead it is to do so via an approved gastight seal, *see also* 3.2.5.

3.1.5 Access hatches and all other openings to cargo tanks, such as ullage and tank cleaning openings are to be located on deck.

3.1.6 Ships carrying toxic products are to be equipped with at least one instrument designed and calibrated for testing for the vapours. For measuring flammable products, *see* 4.7.

3.2 Cargo pumps and compressors

3.2.1 Pumps for the purpose of filling or emptying the cargo tanks or compressors pumping cargo gas back to shore or to re-liquefy cargo vapour and return it to the cargo tanks are to be used exclusively for this purpose and are to be situated in the cargo zone. They are not to have any connections to compartments outside the range of cargo tanks. This is not applicable for Type N-open tankers with the exemption for tankers carrying corrosive cargoes of class 8.

3.2.2 Means are to be provided for stopping the cargo pumps or compressors from a position outside the cargo zone, as well as at the pumps, or compressors.

3.2.3 Pump suction and discharge pressure gauges are to be provided at the pumps or compressors and are to be readable at the pump control stations at all times.

3.2.4 The pumps or compressors are to be provided with effective relief valves which are to be in close-circuit, i.e. discharging to the suction side of the pumps. Alternative proposals to safeguard against over-pressure on the discharge side of the pump will be specially considered.

3.2.5 Where cargo pumps are driven by shafting which passes through a pump-room bulkhead or deck, gastight glands are to be fitted to the shaft at the pump-room plating. The glands are to be efficiently lubricated from outside the pump-room. The seal parts of the glands are to be of materials that will not initiate sparks. The glands are to be of an approved type and are to be attached to the bulkhead in accordance with Ch 11,2.5. Where a bellows piece is incorporated in the design, it is to be hydraulically tested to 3,4 bar before fitting. Bulkhead penetrations with nitrogen seals with an air back up will be specially considered.

3.2.6 Where cargo pumps are driven by hydraulic motors which are located inside cargo tanks, the design is to be such that contamination of the operating medium with cargo liquid cannot take place under normal operating conditions.

3.2.7 Pumps and compressors situated on deck are to be fitted in a position not less than 6 m away from entrances and openings of accommodation and service spaces outside the cargo zone. This is not applicable to Type N-open tankers with the exemption for tankers carrying corrosive cargoes of class 8.

3.3 Cargo piping systems

3.3.1 Cargo pipes are to be situated in the cargo zone and are not to pass through cofferdams or through tanks or compartments which are outside the cargo zone and are to be completely separate from any other piping system. This is not applicable for Type N-open tankers with the exemption for tankers carrying corrosive cargoes of class 8. Cargo pipes are to be clearly marked to distinguish them from other piping systems.

3.3.2 Means are to be provided to enable the contents of the cargo lines and pumps to be drained to a cargo tank or other suitable tank. Where drain tanks are fitted in pump-rooms, they are to be of the closed type with air and sounding pipes led to the open deck.

3.3.3 For bunkering vessels where the contents of the cargo lines in way of the connection with the bunkering gig could not be drained as indicated above separate drainage arrangements are to be provided.

3.3.4 Expansion joints of approved type or bends are to be provided, where necessary, in the cargo pipe lines. Mechanical joints of the slip type may be used only in cargo oil lines. *See* Table 10.2.5 in Chapter 10.

3.3.5 No cargo piping may be arranged under deck, except inside cargo tanks and pump rooms. This is not applicable for Type N-open tankers with the exemption for tankers carrying corrosive cargoes of class 8.

3.3.6 All cargo pipes and their associated fittings are to be tested after assembly on board by hydraulic pressure as per Ch 10,9. In no case is the hydraulic test pressure to be less than 10 bar.

3.3.7 Type C and N tankers are to be provided with a fixed installed stripping system. *See also* 1.4.6.

3.3.8 Loading and discharge lines for Type C tankers, with the exemption of the shore connections, are to be so arranged that no part is situated nearer the side of the ship than B/4.

3.3.9 The loading and discharge lines and vapour collecting lines for Type G tankers, with the exemption of the shore connections but including the safety valves, are to be arranged, together with the relevant segregation devices and valves, between the outside boundary of the dome and B/4.

3.3.10 The above is not applicable to safety discharge pipes. If, however only one dome is present at centre line ship these pipes are to be situated at a minimum distance from the shipside of not less than 2,7 m.

3.4 Terminal fittings at cargo loading stations

3.4.1 Terminal pipes, valves and other fittings in the cargo loading, discharging and vapour return lines, to which shore installation hoses are connected, are to be steel or approved ductile material from the point of connection up to and including the terminal valves. They are to be of robust construction and strongly supported, *see also* 1.3 and 1.4.

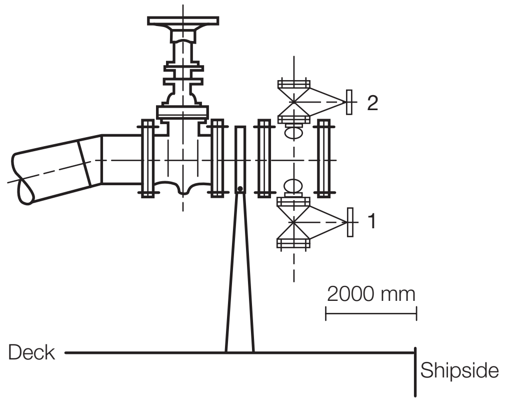
3.4.2 Shore connections of the cargo loading, discharging and vapour return lines are to be provided with a valve. When not in use, they are to be provided with a blind flange.

3.4.3 For Type G tankers, one remotely operated emergency shutdown valve (quick closing valve) is to be provided in addition to the valve as per 3.4.2.

3.4.4 The cargo loading and discharge lines in way of the cargo loading station for Type C and N tankers are to be provided with a connection as per Fig. 13.3.1 for the delivery of residual cargoes.

3.4.5 Bunker ships or other ships capable of discharging oil fuel, lubricating oil, hydraulic oil, etc. to other ships are to be provided with a quick closing valve of ductile material in the discharge pipe. The valve is to be capable of being closed independent of the remote control, *see also* 3.7.

3.4.6 The valve closure time required in the above paragraph is to be such as to avoid surge pressures in the piping system. The valve closure time is to be verifiable and reproducible.



1. Connection for delivery of residual cargo
   Connection conform CEFIC
2. Connection for the shore installation to discharge the residual cargo by means of gas pressure
   Connection conform CEFIC

CEFIC stands for European Chemical Industry Council

Fig. 13.3.1
Connection for the delivery of residual cargoes

3.5 Cargo segregation

3.5.1 Piping systems which serve tanks containing incompatible cargoes are to be isolated from each other by means of removable pipe lengths and blank flanges. Isolating shut-off valves, single or double, or spectacle flanges are not acceptable as equivalent arrangements.

3.5.2 Cargoes, residues of cargoes or mixtures containing cargoes which react in a hazardous manner with other cargoes, residues or mixtures should:

(a) be segregated from such other cargoes by means of a cofferdam void space, cargo pump room, pump-room, empty tank or tank containing a mutually compatible cargo;
(b) have separate pumping and piping systems which should not pass through other cargo tanks containing such cargoes, unless encased in a tunnel; and
(c) have separate tank venting systems.

3.6 Connections to cargo tanks

3.6.1 Where cargo tanks are provided with direct filling connections, the loading pipes are to be led to as low a level as practicable inside the tank.

3.6.2 Where cargo suction and/or filling lines are led through cargo tanks, the connection to each tank is to be provided with a valve secured to the bulkhead and situated inside the tank, and capable of being operated from the deck. Where a pump can be used for more than one cargo tank, shut-off valves are to be provided in the pump-room. For Type N tankers this valve is to be fitted not less than 0,60 m above the bottom.

3.6.3 Cargo lines on Type G tankers are not to be used for ballast purposes.

3.6.4 For Type C and N tankers, the piping system is to be so arranged that water for cleaning out the cargo tanks or for ballasting the ship, is to be taken from a suction pipe situated inside the cargo zone but outside the cargo tanks. At the junction with the cargo filling pipes a screw-down non-return valve is to be fitted.

3.6.5 On Type C or N tankers, pumps for tank wash systems, including their connections, may be situated outside the cargo zone subject to:

- The discharge side of the system is arranged such, that suction through this pipeline is not possible.
- A spring loaded non-return valve, is to be fitted in the discharge pipe when entering the cargo zone.

3.6.6 The connections on the tank domes for Type G tankers with two cargo tanks situated side by side are to be arranged at the dome part facing the centre line of the ship only. Connections positioned at the centre line dome parallel to the centre line of the ship are acceptable accordingly. The valves are to be fitted as close as practicable to the dome.

3.6.7 All liquid and vapour connections on Type G tankers at each cargo tank dome, except safety relief valves and liquid level gauging devices are to be equipped with a manually operated stop valve and a remotely controlled emergency shut down valve. These valves are to be located as close to the tank as practicable. Where the pipe size does not exceed 50 mm in diameter, excess flow valves may be used in lieu of the emergency shut down valve.

3.7 Remote control valves

3.7.1 Valves which are provided with remote control are, in general, to be arranged for local manual operation independent of the remote operating mechanism, *see also* Ch 11,2.4.

3.7.2 Where the valves and their actuators are located inside the cargo tanks, hydraulic (not pneumatic) means for operating the valve actuators are to be provided.

3.7.3 Emergency means are to be provided for operating the valve actuators in the event of damage to the main hydraulic circuits on deck. This could be achieved by ensuring that the supply lines to the actuators are led vertically inside the tanks from deck, and that connections, with the necessary isolating valves, are provided on deck for coupling to a portable pump carried on board.

3.7.4 All actuators are to be of a type which will prevent the valves from opening inadvertently in the event of the loss of pressure in the operating medium. Indication is to be provided at the remote control station showing whether the valve is open or shut.

3.7.5 Materials of construction of the actuators and piping inside the cargo tanks are to be suitable for use with the intended cargoes. *See* 1.3.

3.7.6 The control system for all required emergency shutdown valves is to be so arranged that all such valves may be operated by single controls situated in at least two remote locations on the ship. One of these locations is to be from a position from which all the cargo tanks can be controlled or from the cargo control room.

3.8 Flanges and glands

3.8.1 On Type C tankers, flanges in cargo lines and glands on cargo tanks or lines are to be fitted with adequate arrangements to prevent any accidental spray of cargo.

3.8.2 On Type N tankers, flanges in cargo lines and glands on cargo tanks or lines are to be fitted with adequate arrangements to prevent any accidental spray of cargo when it is intended to carry corrosive cargoes.

3.9 Ship's cargo hoses

3.9.1 Liquid and vapour hoses, used for cargo transfer should be compatible with the cargo and suitable for the cargo temperature.

3.9.2 Details of such hoses are to be submitted together with a type test certificate issued by a recognized Authority.

3.9.3 Hoses subject to tank pressure or the discharge pressure of the pumps should be designed for a bursting pressure of not less than 5 times the maximum pressure the hose will be subjected to during cargo transfer.

3.9.4 Each new type of cargo hose, complete with end fittings should be prototype-tested to a pressure not less than 5 times its specified maximum working pressure. The hose temperature during this prototype test should be the highest and/or lowest service temperature for which the hose is intended.

3.9.5 Hoses used for prototype testing should not be used for cargo service.

3.9.6 Thereafter, before being placed in service, each new length of cargo hose should be hydrostatically tested at ambient temperature to a pressure not less than 1,5 times its specified maximum working pressure but not more then two-fifths of its bursting pressure.

3.9.7 The hose should be stencilled or otherwise marked with the date of testing, its specified maximum working pressure and, if used in other than ambient temperature services, its maximum and minimum service temperature as applicable.

3.9.8 The specified maximum working pressure should be not less than 10 bar gauge.

3.9.9 For Type G tankers, 3.9.10 to 3.9.13 will also be applicable.

3.9.10 Each new type of cargo hose, complete with end fittings, should be prototype-tested at a normal ambient temperature with 200 pressure cycles from zero to at least twice the specified maximum working pressure.

3.9.11 After this cycle test pressure has been carried out, the prototype test should demonstrate a bursting pressure as per 3.9.3 and 3.9.4.

3.9.12 It is assumed that the hoses referred to are ship-to-shore or ship-to-ship hoses which are traditionally considered to be outside the scope of classification. The design, construction and testing of such hoses are to be for the relevant National or Port Authority to approve.

3.9.13 Materials having a melting point below 925°C should not be used for piping outside the cargo tanks except for short lengths of pipe attached to the cargo tanks, in which case fire-resisting insulation should be provided. This temperature limitation indicates that any hoses for use in cargo systems on board ship are to be of metallic construction having a melting point higher than 925°C.

3.9.14 For general requirements on rubber hoses, *see* Ch 10,8.

3.10 Slop tanks and vessels intended for slops for Type C tankers and Type N tankers

3.10.1 Type C and N tankers are to be provided with at least one slop cargo tank and, so far as applicable, with drums for slops which cannot be pumped.

3.10.2 Slop tanks and drums, intended for slobs, are to be located in the cargo zone only.

3.10.3 IBCs (Intermediate Bulk Containers) or portable tanks may be used instead of a fixed residual cargo tank based on special consideration.

3.10.4 Slop tanks For Type N closed tankers and Type C tankers are to be provided with:

- A high velocity valve in compliance with 5.1.2 as far as applicable.
- A vacuum valve in compliance with 5.1.2 as far as applicable.
- A vacuum valve in compliance with 5.2.3 (e) when explosion protection is required as per the A.D.N.R. Table C, Column 17.
- A high velocity vent valve in compliance with 5.2.3 (c) when explosion protection is required as per the A.D.N.R. Table C, Column 17.
- A sounding device of approved type.
- Connections with valves intended for pipes and hoses.

3.10.5 Slop tanks For Type N-with wire gauze tankers are to be provided with:

- A flame arresting pressure equilibrium device.
- A sounding opening.
- Connections with valves intended for pipes and hoses.

3.10.6 Slop tanks for Type N open tankers are to be provided with:

- A pressure equilibrium device.
- A sounding opening.
- Connections with valves intended for pipes and hoses.

3.10.7 IBCs or tank containers for collecting slobs are to be provided with:

- A connection for venting gases in a safe manner during filling operations.
- A sounding arrangement of approved type.
- Connections with valves intended for pipes and hoses.

3.10.8 Slop tanks, IBCs and tank containers are not to be connected to the vapour return system of the cargo tanks except in case the slob tanks or containers are filled.

3.10.9 Slop tanks shall not be connected to a common pipe system when incompatible cargoes will be carried simultaneously, *see* 3.5.

■ *Section 4* Cargo tanks for Type G tankers

4.1 General

4.1.1 Pressure vessels intended for Type G tankers are independent tanks of the domed type. Fittings for the cargo piping system are to be mounted on the domes above the open deck (*see* 3.6.6) All instrumentation and other connections are to be also accessible from the open deck.

4.1.2 The tanks are to be provided with at least one manhole with access from the open deck

4.1.3 The pressure vessels are to comply with 4.2 to 4.8 and, as far as applicable with the requirements of Chapter 4 for independent Type C tanks of the Rules for Ships for Liquefied Gases.

4.2 Cargo tank design

4.2.1 Scantlings based on internal pressure should be calculated as follows:

(a) The thickness and form of pressure-containing parts of pressure vessels under internal pressure, including flanges should be determined according to an acceptable standard. These calculations in all cases should be based on generally accepted pressure vessel design theory. Openings in pressure-containing parts of pressure vessels should be reinforced in accordance with an acceptable standard.

(b) The design liquid pressure defined in 4.3.2 should be taken into account in the above calculations.

(c) The welded joint efficiency factor to be used in the calculation according to 4.2.1(a) is depending on inspection and non-destructive testing requirements. See for guidance the Rules for Liquefied Gases Ch 4,4.4.6.3.

4.3 Design loads

4.3.1 **General**. The independent tanks together with the supports and other fixtures should be designed taking into account proper combinations of the following loads:

- Internal pressure
- External pressure
- Loads on supports.

4.3.2 **Internal pressure**. The internal pressure head P_{eq} in bars gauge resulting from the design vapour pressure P_o and the liquid pressure P_{gd} should be calculated as follows:

$$P_{eq} = P_o + (P_{gd})_{max} \text{ (bar)}$$

4.3.3 **External pressure**. External design pressure loads should be based on the difference between the maximum internal pressure (maximum vacuum) and the maximum external pressure to which any portion of the tank may be subjected simultaneously .

4.3.4 The loads on supports are covered by the Section 4.5.

4.4 Allowable stresses

4.4.1 For independent tanks the maximum allowable membrane stress to be used in the calculation according to 4.2.1.1 will be specially considered.

4.4.2 For guidance reference is made to the Rules for Ships for Liquefied Gases Ch 4,4.5.

4.5 Supports

4.5.1 Cargo tanks should be supported by the hull in a manner which will prevent bodily movement of the tanks while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and of the hull.

4.5.2 Tank supports are generally to be located in way of the primary structure of the tank and the ship's hull. Steel seatings are to be arranged, where possible on both the floors and underside of the cargo tank so as to ensure an effective distribution of the transmitted load and reactions into the cargo tanks and ship's structure.

4.5.3 Suitable supports should be provided to withstand a collision force acting on the tank corresponding to half the weight of the tank and cargo in the forward direction and one quarter of the weight of the tank and cargo in the aft direction without deformation likely to endanger the tank structure.

4.5.4 Anti flotation arrangements should be provided for independent tanks. The anti flotation arrangements should be suitable to withstand an upward force caused by an empty tank in a hold space flooded to T_{max} + 0,4 m in which T_{max} is the maximum draught of the ship, without plastic deformation likely to endanger the hull structure.

4.5.5 An adequate clearance is to be provided between the anti flotation chocks and the ship's hull in all operational conditions.

4.5.6 The support arrangements should be designed for the full weight of the tanks together with holding down arrangements.

4.5.7 The tank seatings shall be capable to keep the tank in place for a total heeling range up to and including the total capsized condition.

4.5.8 The saddles are to be extended to a point of not less than 10º below the horizontal centre line of the pressure vessel.

4.6 Construction and testing

4.6.1 All welded joints of the shells of independent tank should be of the butt weld, full penetration type.

4.6.2 Workmanship is to be to the satisfaction of LR and to the requirements of Chapter 14,2 for Class 1 pressure vessels.

4.6.3 Independent tanks should be subjected to a hydrostatic test or alternatively to a hydro pneumatic test as per Chapter 4, Section 4.10.10.3 for Type C independent tanks of the Rules for Ships for Liquefied Gases.

4.7 Inspection and non-destructive testing

4.7.1 For independent tanks, inspection and non-destructive testing should be as far as applicable in compliance with Chapter 4, Section 4.10.9 of the Rules for Ships for Liquefied Gasses.

4.8 Corrosion Allowance

4.8.1 For pressure vessels no corrosion allowance is generally required if the contents of the pressure vessel are non-corrosive and the external surface is protected by inert atmosphere or by an appropriate insulation with an approved vapour barrier. Paint or other thin coatings should not be credited as protection. Where special alloys are used with acceptable corrosion resistance, no corrosion allowance should be required. If the above conditions are not satisfied, the scantlings calculated according to 4.2 should be increased as appropriate.

■ *Section 5* Cargo tank venting arrangements

5.1 General

5.1.1 Each cargo tank and slop tank or group of cargo tanks or slop tanks connected by means of a vapour collecting pipe system is to be fitted with venting arrangements which will limit the pressure or vacuum in the tank, and are to comply with the requirements of this Section. The vapour collecting system of slop tanks are normally separated and distinct from the cargo tanks, *see* 3.10.8.

5.1.2 Cargo tank venting arrangements are to be designed to provide:

(a) pressure/vacuum release of small volumes of vapour/air mixtures flowing during a normal voyage;

(b) venting of large volumes of vapour/air mixtures during cargo handling and gas freeing operations; and

(c) a secondary means of allowing full flow relief of vapour, air or inert gas mixtures to prevent overpressure or underpressure in the event of failure of the arrangements in 5.1.2(b). Alternatively, pressure sensors may be fitted to monitor the pressure in each tank protected by the arrangement required in 5.1.2(b), with a monitoring system in the ship's cargo control room or the position from which cargo operations are normally carried out. Such monitoring equipment is also to provide an alarm facility which is activated by detection of overpressure or underpressure conditions within a tank.

5.2 Pressure/vacuum and venting systems for various tanker types

5.2.1 **Type N-open**. Each cargo tank is to be in open connection with the atmosphere through a vapour pipe, or equivalent, of sufficient cross-sectional area. Provision is to be made to prevent collection or the entrance of water into the cargo tanks by approved means or appliances.

5.2.2 **Type N-open, with flame arrestor**. Arrangements as for Type N-open ships, except that vapour pipes, or equivalent, are to be provided with readily renewable flame arrestors or safety heads of approved type suitable to withstand a long burning proof. Material of wire gauzes is to be resistant to corrosion. Provision is to be made to prevent collection or the entrance of water into the cargo tanks by approved means or appliances.

5.2.3 **Type C and N-closed.** Each cargo tank or group of cargo tanks connected to a common vapour pipe is to be provided with:

(a) means to prevent the tanks being subjected to an overpressure exceeding 115 per cent of the set pressure the high velocity valve or to an under pressure exceeding 110 per cent of the set pressure of the vacuum valve with a maximum of 5 kPa during the voyage and any phase of the cargo handling;

(b) connections for returning the vapour to shore when loading cargo. These connections are to be provided with a positive means of closing, *see* 3.4;

(c) an approved type high velocity vent capable of resisting a long burning proof. Vapour should be discharged in an upward vertical direction.

(d) at each cargo tank connected to a common vapour pipe, a device should be fitted at the inlet of the vapour pipe to prevent the passage of flames and being capable of resisting a detonation in the common vapour pipe. The required device is to be of an approved type.

(e) a vacuum valve of an approved type and provided with a wire gauze capable of resisting a deflagration.

(f) a device of approved type to depressurize the cargo tanks in a safe manner. This device is consisting of a flame arrestor capable of resisting a long burning proof and a valve. The position of the valve i.e. open or closed is to be clearly indicated.

(g) high velocity vents to be arranged not less than 2 m above deck and their outlets should also be arranged at a distance of at least 6 m from the accommodation and service spaces positioned outside the cargo area. Openings below 2 m can be accepted provided no handling equipment will be fitted in a radius of 1 m and the area will be clearly marked as dangerous. In no case is the height of the opening to be less than 0,5 m above deck.

(h) a pressure gauge on each cargo tank suitable for under and overpressure measurement.

(j) means for draining liquid in the vent piping system, from places where it may accumulate, should be provided. The high velocity valves and piping are to be so arranged that, under no circumstances, liquid can accumulate in or near the high velocity valves.

(k) If explosion protection is not required as per the A.D.N.R, Table C, Column 17 the following relaxations can be given:
- High velocity vents as per (c) are not required to be of an approved long burning proof type.
- Vacuum valves as per (e) are not required to be provided with a wire gauge capable of resisting a deflagration.
- Detonation devices as per (c) are not required to be fitted.
- Depressurising devices are not to be provided with a flame arrestor capable of resisting a long burning proof as per (f).

(l) Flammable cargoes are banned from the list of dangerous goods for tankers in compliance with the above Section 5.2.3(k).

5.2.4 **Type G.** The requirements of 4.2.5 to 4.2.17 apply.

5.2.5 All cargo tanks are to be provided with a pressure relief system appropriate to the design of the cargo containment system and the cargo being carried. Hold spaces and cargo piping which may be subjected to pressures beyond their design capabilities are also to be provided with a suitable safety relief system. The pressure safety relief system is to be connected to a vent piping system to minimize the possibility of cargo vapour accumulating about the deck or entering accommodation and machinery spaces, or any other space where it may create a dangerous condition.

5.2.6 Each cargo tank with a volume greater than 20 m^3 is to be fitted with at least two pressure relief valves of approximately equal capacity, suitably designed and constructed for the prescribed service. For cargo tanks with a volume less than 20 m^3, a single relief valve may be fitted.

5.2.7 The pressure relief valves should be connected to the highest part of the cargo tank above deck level.

5.2.8 In the vent piping system means, for draining liquid, from places where it may accumulate, should be provided. The pressure relief valves and piping are to be so arranged that, under no circumstances, can liquid accumulate in or near the pressure relief valves.

5.2.9 Pressure relief valves are to be prototype tested to ensure that the valves have the capacity required.

5.2.10 In general, the opening pressure of the safety valves should not be higher than the vapour pressure which has been used in the design of the tank. However, where two or more pressure relief valves are fitted, valves comprising not more than 50 per cent of the total relieving capacity may be set at a pressure up to 5 per cent above MARVS. (Maximum Allowable Relief Valve Setting of a cargo tank).

5.2.11 The pressure relief valves are to have a (combined) relieving capacity for each cargo tank as per the Rules for Ships for Liquefied Gases Ch 8, 8.3 and 8.5.

5.2.12 Each tank is to be provided with a pressure gauge suitable for under and overpressure measurement.

5.2.13 For refrigerating systems, *see* the Rules for Ships for Liquefied Gases, Ch 7,7.2

5.2.14 Each cargo tank in which cooled cargo will be carried is to be provided with a safety device which will prevent inadmissible over and under pressure in the cargo tanks.

5.2.15 For the carriage of cooled cargo, the opening pressure of the safety device is to be established by the arrangement of the cargo tank. For cargoes which are required to be cooled the safety device is to be set not less than 25 kPa above the calculated pressure as intended in the Rules for Ships for Liquefied Gases Ch 7,7.2.

5.2.16 Openings for the relief of gases from the overpressure devices are to be arranged not less than 2 m above deck and their openings should also be arranged of at least 6 m from accommodation and service spaces situated outside the cargo zone. A height of less than 2 m can be accepted provided no handling equipment will be fitted in a radius of 1 m of the discharge opening of the overpressure device and the area will be clearly marked as dangerous.

5.2.17 Suitable protection screens are to be fitted on vent outlets to prevent the ingress of foreign objects.

5.2.18 The design and testing of the devices mentioned in 5.2.2 to 5.2.17 are to comply with the requirements of the relevant National Authorities.

5.3 Design vapour pressure for Type G tankers.

5.3.1 The design vapour pressure P_o is the maximum gauge pressure at the top of the tank which has been used in the design of the tank.

5.3.2 For cargo tanks where there is no temperature control and where the pressure of the cargo is indicated only by the ambient temperature, P_o is not be less than the gauge vapour pressure of the cargo at a temperature of 40°C.

5.3.3 In all cases, including 4.3.2, P_o should not be less than MARVS.

5.4 Design temperature for Type G tankers

5.4.1 The design temperature for selection of materials is the minimum temperature at which cargo may be loaded or transported to the cargo tanks. Provisions to the Society's satisfaction are to be made to ensure that the tank or cargo temperature cannot be lowered below the design temperature.

5.5 Loading and unloading rates for Type C and Type N-closed tankers

5.5.1 Cargo tank venting systems should be designed and operated so as to ensure that neither pressure nor vacuum created in the cargo tanks during loading or unloading exceeds tank design parameters, *see* 5.2.3(a) for maximum allowable cargo tank pressures. The main factors to be considered in the sizing of a tank venting system are as follows:

(a) design loading and unloading rate;
(b) gas evolution during loading: this should be taken account of by multiplying the maximum loading rate by a factor of at least 1,25;
(c) density of the cargo vapour mixture, based on a mixture of 50 vol. per cent vapour and 50 vol. per cent air;
(d) pressure loss in the vent piping and across valves and fittings. Detonation devices and flame arrestors are to be considered in the clogged condition responsible for an additional pressure loss of not less than 30 per cent ;
(e) pressure/vacuum settings of relief devices;
(f) dimensions of the cargo tank venting system.

5.5.2 The maximum permissible loading and unloading rates for each tank or group of tanks consistent with the design of the venting system shall be carried on board.

5.5.3 The maximum permissible loading and unloading rates for each tank or group of tanks are to be limited in order to avoid static electricity, but should in any case not exceed 7 m/sec in the cargo pipes.

5.6 Pressure and temperature control of the cargo for a Type G tanker

5.6.1 Unless the entire cargo system is designed to withstand the full gauge vapour pressure of the cargo under conditions of the upper ambient design temperatures, maintenance of the cargo tank pressure below the MARVS should be provided by one or more of the following means:

(a) A system which regulates the pressure in the cargo tank by the use of mechanical refrigeration.
(b) A system that acceptswarming up and rise of pressure. The insulation together with the design pressure of the cargo tank are to be capable to guarantee an appropriate safety in respect of the period of operation and working temperature. The safety of at least three times the period of operation is to be guaranteed.
(c) Any other system acceptable to the Society.

For requirements of the above systems, *see* 1.1.8.

5.6.2 The above systems should be constructed, fitted and tested to the satisfaction of the Society. Materials used in the construction should be suitable for use with the cargoes to be carried. For normal service, the upper ambient temperature should be:

- Air temperature : + 30°C.
- Water temperature : + 20°C.

5.6.3 For certain highly dangerous cargoes specified in Table C of the ADNR/ADN , the cargo containment system should be capable of withstanding the full vapour pressure of the cargo under conditions of the upper ambient design temperatures irrespective of any system provided for dealing with boil-off gas (*see* 1.3.8 for Table reference).

5.7 Gas measurement

5.7.1 All tankers are to be equipped with at least one portable instrument for measuring the percentage of LEL of hydrocarbon concentrations in air, together with a sufficient set of spares.

5.7.2 All tankers are to be equipped with at least one portable oxygen analyser.

5.7.3 A sufficient set of spares of the above portable instruments is to be carried on board.

5.7.4 Suitable means are to be provided for the calibration of gas measurement instruments.

■ *Section 6*
Cargo tank level gauging equipment and arrangements against overfilling

6.1 Sounding devices

6.1.1 Each cargo tank is to be fitted with suitable means for ascertaining the liquid level in the tank.

6.1.2 Ullage openings or sighting ports may be fitted to the cargo tanks on Type N-open ships. *See* 5.2.1 for requirements of openings in cargo tanks.

6.1.3 Arrangements which permit the escape of vapour to the atmosphere are not to be fitted in enclosed spaces.

6.2 Closed level indicating devices

6.2.1 The cargo tanks of all types of ships, except the N-open and N-with flame arrestors, are to be fitted with a closed level indicating device of an approved type which does not permit the escape of vapour or cargo when being used. For all types of tankers, the device is to be so positioned that it can be easily read from the operating position for the closing valve on the relevant tank.

6.2.2 Proposals to use indirect sounding or measuring devices, which do not penetrate the tank plating, will be specially considered.

6.3 Precautions against overfilling

6.3.1 Cargo tanks of each type of tanker are to be provided with a mark on the inside showing the level for the following maximum percentage of filling permitted, *see also* 6.3.4:

Type N	97%
Type C	95%
Type G	not applicable.

6.3.2 Cargo tanks of each type of tanker are to be provided with a high level audible and visual alarm set at the following percentage of filling, *see also* 6.3.4:

Type N	90%
Type C	90%
Type G	86%.

6.3.3 In addition to the high level alarm required by 6.3.2 the tanks are to be provided with an independent automatic device for shutting off the supply of cargo, set at the following percentage of filling, *see also* 6.3.4:

Type N	97,5%
Type C	97,5%
Type G	97,5%.

6.3.4 Filling percentages are to be determined in relation to the total capacity of the tanks including any expansion trunk and are to have an accuracy of ±0,5 per cent.

6.3.5 For the maximum allowable cargo related filling limits see ADNR/ADN Table C, Column 11. (*see* 1.3.8 for reference)

6.3.6 Pressure vessels for Type G tankers may not be filled to more than 91 per cent for uncooled and 95 per cent for cooled cargoes. *See* also ADNR/ADN, Part 3, Table C, column 11 (*see* 1.3.8).

6.4 Cargo sampling arrangements

6.4.1 Cargo tanks of all ships are to be provided with suitable connections for a device capable of taking samples of the cargo.

6.4.2 On cargo tanks of Type G ships these devices are to be of the closed type.

6.4.3 On cargo tanks of Type C and N ships these devices are to be of the closed or restricted type. Conform the requirements of ADNR/ADN, Table C, Column 13 (*see* 1.3.8 for reference). The sampling opening is to be in compliance with 6.4.8.

6.4.4 The closed devices are to be so arranged that loss of pressure and appreciable loss of gas is not possible.

6.4.5 The restricted devices are to be so arranged that during sampling only a minor quantity of gaseous or liquid cargo will come into the atmosphere. The arrangement of the device is such that it is completely closed when not used.

6.4.6 On cargo tanks of Type N-with flame arrestor a closed or partly closed sampling device is not required. However, sampling openings are to be in compliance with 6.4.8.

6.4.7 Closed or partly closed sampling devices and sampling openings are not required for Type N-open ships.

6.4.8 The diameter of sampling openings may not exceed 0,30 m. They must be provided with a flame arrestor and are to be so arranged that the opening time can be limited and the wire gauze could not remain in the open position without external influence.

6.4.9 On ships of Type N-Open sampling openings are not required to be fitted with a flame arrestor.

6.4.10 Sampling devices are not required for Type N bunker ships.

6.4.11 The cargo sampling devices are to be of an approved type, accepted by the applicable National Authorities.

■ *Section 7*
Cargo heating arrangements

7.1 General

7.1.1 In addition to the requirements detailed in this Section, the requirements of Ch 12,11 for thermal oil systems to be installed on Type C and N tankers are to be complied with as far as they are applicable.

7.1.2 Outlets of exhaust gas lines from thermal oil heaters are to be provided with spark arrestors or equivalent and are not to be led through the cargo zone. The distance between the outlet and the cargo zone is to be not less than 2 m.

7.1.3 The air intakes from the thermal oil heater are to be so arranged that their openings are not less than 2 m outside the cargo zone and not less than 6 m from openings of cargo or slop tanks, cargo pumps on deck, openings of high velocity vents or over pressure devices and shore connections of the cargo lines. Furthermore, the air intakes are to be arranged not less than 2 m above deck.

7.1.4 Thermal oil heaters are to be situated in the engine room or, alternatively, in a special space outside the cargo zone accessible from deck or from within the engine room.

7.1.5 Where heating systems are provided for the cargo tanks, the arrangements are to comply with the requirements of 7.2 to 7.5.

7.2 Blanking arrangements

7.2.1 Spectacle flanges or spool pieces are to be provided in the heating medium supply and return pipes to the cargo heating system, at a suitable position within the cargo area, so that the lines can be blanked off in circumstances where the cargo does not require to be heated or where the heating coils have been removed from the cargo tanks. Alternatively, blanking arrangements may be provided for each tank heating circuit.

7.3 Heating medium

7.3.1 The heating medium is to be compatible with the cargoes to be heated. Where a cargo is highly water reactive, water or steam is not to be used as the medium. For lists of chemicals containing information on water reactivity, *see* ADNR/ADN, Table C (*see also* 1.3.8).

7.3.2 Where a combustible liquid is used as the heating medium, it is to have a flash point of 55°C or above (closed cup test).

7.3.3 In general, the temperature of the heating medium is not to exceed 220°C.

7.4 Heating circuits

7.4.1 The heating medium supply and return lines are not to penetrate the cargo tank plating, other than at the top of the tank, and the main supply lines are to be run above the deck.

7.4.2 Isolating shut-off valves or cocks are to be provided at the inlet and outlet connections to the heating circuit(s) of each tank, and means are to be provided for regulating the flow.

7.4.3 In case of direct heating arrangements valves for the individual heating coils are to be provided with locking arrangements to ensure that the coils are under static pressure at all times.

7.4.4 For direct heating systems, isolation valves are to be provided in the cargo heating supply and return line in a readily accessible position in the cargo zone.

7.4.5 Where steam or water is employed in the heating circuits of Type N-open ships, the returns are to be led to an observation tank, which is to be in a well ventilated and well lighted part of the machinery space remote from highly heated surfaces or possible sources of ignition.

7.4.6 Where a thermal oil is employed in the heating circuits, the arrangements are to be such that contamination of the thermal oil with cargo liquid cannot take place under normal operating conditions.

7.4.7 A heat exchanger, situated in the cargo zone, is to be incorporated in the heating systems of tankers carrying toxic cargoes Class 6.1. In these cases the tank heating circuits are also to lie entirely within the cargo zone.

7.4.8 A heat exchanger for toxic cargoes may be waived where the medium is sampled to check for the presense of cargo before it is re-circulated to other services of the ship or into the machinery space. The sampling equipment should be located within the cargo area and be capable of detecting the presence of any toxic cargo being heated. Where this method is used, the coil return should be tested not only at the commencement of heating of a toxic product, but also on the first occasion the coil is subsequent to having carried an unheated toxic cargo.

7.4.9 In any heating system a positive pressure in the coils of at least 30 kPa above the static liquid pressure of the cargo, increased with the relevant set pressure of the high velocity valve as far as applicable, shall be maintained under all conditions of service when the circulation pump is not in operation.

7.4.10 Alternatively, the heating system may be drained and blanked when the circuit is not in use, provided the heating system is to be verified on the presence of previous cargo at the commencement of heating another product.

7.4.11 Arrangements are to be provided to monitor the pressure in the heating coils.

7.4.12 The heating system shall not be used during cargo operations. When, however this is unavoidable, the arrangements for electrical equipment, ventilation and gas detection for the space where the boiler or thermal oil heater is located will be specially considered. However, for cargoes with a flash point exceeding 61°C , when the temperature of the product will be at least 15°C below the flash point, the heating system may be used during cargo operations without special consideration.

7.4.13 In view of the dangerous situation which may arise in the event of contamination of the thermal fluid with low flash cargo oil, for oil and chemical tankers intended for the carriage of products having a flash point below 55°C, permanent notice boards should be displayed in prominent positions in the engine room and on deck, stating that the thermal oil system should remain under pressure, *see also* 7.4.9, except when the ship is either carrying cargoes having a flash point above 55°C, or the cargo tanks are empty and gas free and will be pressurised again before low flash oil is loaded.

7.5 Temperature indication

7.5.1 Means are to be provided for measuring the cargo temperature. Where overheating could result in a dangerous condition, an alarm system which monitors the cargo temperature is to be provided.

■ *Section 8* Cargo temperature control arrangements

8.1 Temperature measurement

8.1.1 All cargo tanks are to be fitted with cleary legible devices indicating the mean temperature of the cargo from a position where cargo operations are carried out.

8.1.2 For the maximum allowable temperature, *see* ADNR/ADN, Table C , Column 20 (*see* 1.3.8 for reference).

8.2 Water spray system

8.2.1 Where settlement of vapour is required on Type G or Type C tankers, or cooling is required to retain the cargo temperature within the limits of safe carriage on Type N or Type C tankers, a water spray system with a capacity of not less than 50 litres/m^2 deck area cargo zone per hour is to be provided on deck.

8.2.2 This water spray system is to be capable of being connected to a shore supply.

8.2.3 The water spray system is to be controlled from the wheelhouse as well as on deck.

8.2.4 For cargoes for which a water spray system is mandatory, *see* list of chemicals in ADNR/ADN, Table C, Column 9 (*see* 1.3.8).

■ *Section 9* Inert gas systems

9.1 General

9.1.1 Where an inert gas system is fitted, the arrangements are to comply with the following requirements and, as far as applicable, with the requirements of Pt 5, Ch 15,7 of the *Rules and Regulations for the Classification of Ships*. Consideration will be given to special cases where the arrangements are equivalent to those required by the Rules.

9.1.2 The space containing the Inert Gas generator is to be provided with visible and audible alarms for oxygen concentration. The sensors are to be located in positions where potentially dangerous concentrations may be readily detected.

9.1.3 The permeate outlet is to be led to a safe position as far as possible from any source of ignition. The pipe is of sufficient diameter in order to achieve very low velocities of the oxygen.

9.1.4 Spaces containing inert gas generating plants should have no direct access to accommodation spaces, service spaces or control stations, but may be located in machinery spaces.

9.1.5 Inert gas piping should not pass through accommodation spaces, service spaces or control stations.

9.1.6 When not in use, the inert gas system should be made separate from the cargo system in the cargo area except for connections to the hold spaces or interbarrier spaces.

9.1.7 Flame burning equipment for generating inert gas will be specially considered.

9.2 Type C tankers and Type N-open tankers

9.2.1 One or more pressure-vacuum breaking devices are to be provided to prevent the cargo tanks from being subject to:

(a) a positive pressure in excess of the test pressure of the cargo tank if the cargo were to be loaded at the maximum rated capacity and all other outlets were left shut; and

(b) a negative pressure in excess of 5 kPa if cargo were to be discharged at the maximum rated capacity of the cargo pumps and the inert gas blowers were to fail.

Such devices shall be installed on the inert gas main unless they are installed in the venting system required by Section 4 or on individual cargo tanks.

9.2.2 The set pressure of the vacuum valve required by 5.2.3(a) is to be 3,5 kPa.

9.2.3 The inert gas system is to be capable to maintain a pressure, under all conditions of service, of not less than 7 kPa in the tanks to be inerted.

9.2.4 Sufficient quantities of inert gas shall be available on board to compensate the losses during voyage.

9.2.5 Portable instruments for measuring oxygen and flammable vapour concentration are to be provided. In addition, suitable arrangement is to be made on each cargo tank such that the condition of the atmosphere can be determined using these portable instruments.

9.2.6 An Inert gas main is to be provided. The inert gas main may be divided into two or more branches forward of the deck main isolation valve.

9.2.7 The inert gas discharge may be connected with the vapour return system for ships carrying cargoes for which inert gas is not mandatory as per the ADNR, Table C, Column 20, additional requirements. Two means of isolation as per 9.2.8 or 9.2.9 are to be provided in the connection to the vapour return line. In addition a removable spool piece is to be provided on the cargo tank side of the connection. A notice is to be provided located in a prominent position adjacent to the means of isolation, clearly indicating that the spool piece is to be removed and blanking flanges are to be fitted, when the inert gas system is not in use. The removable spool piece is to be clearly identified (labelled/painted in a distinctive colour) and stowed close to its working position.

9.2.8 At least two non-return devices, one of which shall be a water seal, shall be fitted in the inert gas supply main or in the inert gas discharge connection to the vapour return system as applicable, in order to prevent the return of hydrocarbon vapour to any gas-safe spaces under all normal conditions of trim and list. They shall be located between the automatic delivery valve fitted to the forward bulkhead of the forward most gas-safe space and the aftermost connection to any cargo tank.

9.2.9 If a water seal, as required by 9.2.8, is impracticable, it may be substituted by a double block and bleed system. Details of this system are to be submitted for approval.

9.3 Type G tankers

9.3.1 The inert gases should be compatible chemically and operationally, at all temperatures likely to occur within the spaces to be inerted, with the materials of construction of the cargo.

9.3.2 Where inert gas is also stored for fire-fighting purposes, it should be carried in separate containers and should not be used for cargo services.

9.3.3 Arrangements suitable for the cargo carried should be provided to prevent the backflow of cargo vapour into the inert gas system.

9.3.4 The arrangements should be such that each space being inerted can be isolated and the necessary controls and relief valves, etc. should be provided for controlling pressure in these spaces.

9.3.5 Inert gas systems are to be so designed as to minimise the risk of ignition from the generation of static electricity by the system itself.

9.3.6 The equipment should be capable of producing inert gas with an oxygen content at no time greater than 5 per cent by volume. A continuous-reading oxygen content meter should be fitted to the inert gas supply from the equipment and should be fitted with an alarm set at a maximum of 5 per cent oxygen content by volume. The above is subject to the special requirements of Table C of Part 3 of the ADNR/ADN where a lower maximum oxygen content may be specified for specific cargoes.

9.3.7 An inert gas system should have pressure controls and monitoring arrangements appropriate to the cargo containment system. Acceptable means, located in the cargo area, of preventing the backflow of cargo gas should be provided.

9.3.8 If the inert gas plants are located in machinery spaces or other spaces outside the cargo area, two non-return valves, or equivalent devices should be fitted in the inert gas main in the cargo area as required in 9.3.7.

■ *Section 1* General

1.1 Scope

1.1.1 The requirements of this Chapter apply to the welding of pressure vessels and pressure pipes. The allocation of Class is determined from the design criteria referenced in Chapters 8, 9 and 10.

1.1.2 Fusion welded pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding required for the Class of vessel proposed.

1.1.3 The term 'fusion weld', for the purpose of these requirements, is applicable to welded joints made by manual, semi-automatic or automatic electric arc welding processes. Special consideration will be given to the proposed use of other fusion welding processes, *see* Section 6 for oxy-acetylene welding of pipes.

1.1.4 For pressure vessels which only have circumferential seams, *see* Ch 9,1.5.5.

1.1.5 Requirements for fusion welding of pressure vessels and piping of other recognized Codes or standards, giving an equivalent level of quality, can be accepted.

1.2 General requirements for welding plant and welding quality

1.2.1 In the first instance, and before work is commenced, the Surveyors are to be satisfied that the required quality of welding is attainable with the proposed welding plant, equipment and procedures.

1.2.2 The procedures are to include the regular systematic supervision of all welding, and the welders are to be subjected by the works' supervisors to periodic tests for quality of workmanship. Records of these tests are to be kept and are to be available for inspection by the Surveyors.

1.2.3 All welding is to be to the satisfaction of the Surveyors.

■ *Section 2* Manufacture and workmanship of fusion welded pressure vessels

2.1 General requirements

2.1.1 Prior to commencing construction, the design of the vessel is to be approved, where required, by Ch 8,1.2 and Ch 9,1.6.

2.1.2 Pressure vessels will be accepted only if manufactured by firms that have been assessed and approved as indicated in 2.1.3 to 2.1.6.

2.1.3 Class 1 and Class 2/1 fusion welded pressure vessels constructed to Class 1 and Class 2/1 requirements will be accepted only if manufactured by firms equipped and competent to undertake high quality welding. In order that firms may be approved for this purpose, it will be necessary for the Surveyor to visit the works for the purpose of inspecting the welding plant, equipment and procedures, and to arrange for the carrying out of preliminary tests as referred to in 2.1.8.

2.1.4 Class 2/2 pressure vessels made in accordance with Class 2/2 requirements, will be accepted only if constructed by firms whose works are properly equipped to undertake the welding of pressure vessels of this Class.

2.1.5 It will be necessary for the Surveyor to visit the works for the purpose of inspecting the welding plant, equipment and procedures, and to arrange for the carrying out of preliminary tests as referred to in 2.1.8.

2.1.6 Class 3 pressure vessels will be accepted if constructed by firms whose works are equipped to undertake the welding of pressure vessels of this Class.

2.1.7 It will be necessary for the Surveyor to visit the works for the purpose of inspecting the welding plant, equipment and procedures, and to arrange for the carrying out of preliminary tests to demonstrate the quality of the welding. These tests are to be carried out by the firm under the supervision of the Surveyor. The test requirements will be based on the welding process used, but are to be similar to those described in 3.4.4 and 3.4.5.

2.1.8 For preliminary tests, *see* the *Materials and Qualification Procedures for Ships*, Book A, MQPS 0-4, Section 4.1.

2.2 Materials of construction

2.2.1 Materials used in welded construction are to be readily weldable and shall have proven weldability.

2.2.2 Materials are to be supplied by firms that have been approved in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as Rules for Materials).

2.2.3 Where the construction details are such that materials are subject to through thickness strains, consideration should be given to using materials with specified through thickness properties as specified in Ch 3,8 of the Rules for Materials.

2.2.4 Where the construction requires post-weld heat treatment, consideration should be given to certifying the material after subjecting the test pieces to a simulated heat treatment.

2.2.5 The identity of materials is to be established by way of markings, etc., so that traceability to the original manufacturer's certificate is maintained.

2.3 Cutting of materials

2.3.1 Materials may be cut to the required dimensions by thermal means, shearing or machining in accordance with the manufacturing drawings or specifications.

2.3.2 Cold shearing should not be used on materials in excess of 25 mm thick and, where used, the cut edges are to be cut back by machining or grinding for a minimum distance of 3 mm.

2.3.3 Material which has been thermally cut, is to be machined or ground back to remove all oxides, scale and notches.

2.3.4 Thermal cutting of alloy and high carbon steels may require the application of preheat, and special examination of these cut edges will be required to ensure freedom from cracking. In these cases the cut edges are to be machined or ground back a distance of at least 2 mm, unless it has been demonstrated that the cutting process has not damaged the material.

2.3.5 Any material damaged in the process of cutting is to be removed by machining, grinding or chipping back to sound metal; weld repair may only be performed with the agreement of the Surveyors.

2.3.6 All plate edges, after being cut, shall be examined for defects, including laminations, to ensure that these are free from cracks. Visual methods may be augmented by other techniques at the discretion of the Surveyors.

2.3.7 Edges that have been cut by machining or chipping, which will not be subsequently covered by weld metal, are to be ground smooth.

2.4 Forming shell sections and end plates

2.4.1 Shell plates and heads are to be formed to the correct contour up to the extreme edge of the plate.

2.4.2 Plates may be formed to the required shape either hot or cold and by any process that does not impair the quality of the material. Tests to demonstrate the suitability of the forming process may be requested at the discretion of the Surveyors.

2.4.3 Wherever possible, forming is to be performed by the application of steady continuous loading using a machine designed for that purpose. The use of hammering, in either the hot or cold condition should not be employed.

2.4.4 Material may be welded prior to forming or bending, provided that it can be demonstrated that the mechanical properties of the welds are not impaired by the forming operation. All welds subjected to bending are to be inspected on completion to ensure freedom from surface breaking defects.

2.4.5 Vessels manufactured from carbon or carbon manganese steel plates which have been hot formed or locally heated for forming are to be re-heat treated in accordance with the original supplied condition on completion of this operation. Vessels formed from plates supplied in the as-rolled condition shall be heat treated in accordance with the material manufacturer's recommendations.

2.4.6 Where these steels are supplied in the as-rolled, normalized or normalized rolled condition, if hot forming is carried out entirely at a temperature within the normalizing range, subsequent heat treatment will not be required.

2.4.7 For alloy steel vessels, where hot forming is employed, the plates are to be heat treated on completion in accordance with the material manufacturer’s recommendations.

2.4.8 Where plates are cold formed, subsequent heat treatment is to be performed where the internal radius is less than 10 times the plate thickness. For carbon and carbon-manganese steels, this heat treatment may be a stress relief heat treatment.

2.4.9 In all cases where hot forming is employed, and for cold forming to an internal radius less than 10 times the thickness, the manufacturer is required to demonstrate that the forming process and subsequent heat treatments result in acceptable properties.

2.5 Fitting of shell plates and attachments

2.5.1 Careful consideration is to be given to the assembly sequence to be employed, in order to minimize overall shrinkage and distortion and to reduce the build up of residual stresses.

2.5.2 Excessive force is not to be used in fairing and closing the work. Where excessive root gaps exist between surfaces or edges to be joined, the corrective measures adopted are to be to the satisfaction of the Surveyors.

2.5.3 Provision is to be made for retaining correct alignment during welding operations.

2.5.4 In all cases, where tack welds are used to retain plates or parts in position prior to welding, they are to be made using approved welding procedures.

2.5.5 Where temporary bridge pieces or strong-backs are used, they are to be of similar materials to the base materials and are to be welded in accordance with approved welding procedures.

2.5.6 Where welding to clad materials, any fit-up aids and tack welds are to be attached to the base materials and not to the cladding.

2.5.7 The location of welded joints are to be such as to avoid intersecting butt welds in the vessel shell plates. The attachment of nozzles and openings in the vessels are to be arranged to avoid main shell weld seams.

2.5.8 The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other, at any point, by more than 10 per cent of the plate thickness. In no case is the mis-alignment to exceed 3 mm for longitudinal seams, or 4 mm for circumferential seams.

2.5.9 Where a vessel is constructed of plates of different thicknesses (tube plate and wrapper plate), the plates are to be so arranged that their centrelines form a continuous circle.

2.5.10 For longitudinal seams, the thicker plate is to be equally chamfered inside and outside by machining over a circumferential distance not less than twice the difference in thickness, so that the plates are of equal thickness at the longitudinal weld seam. For the circumferential seam, the thickest plate is to be similarly prepared over the same distance longitudinally.

2.5.11 For the circumferential seam, where the difference in the thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the weld joint. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate.

2.6 Welding during construction

2.6.1 Welding plant and equipment is to be suitable for the purpose intended and properly maintained, taking due cognisance of relevant safety precautions. Electrical meters are to be properly maintained and have current calibrations.

2.6.2 Welding consumables are to be suitable for the type of joint and grade of material to be welded and satisfactory storage and handling facilities are to be provided close to working areas.

2.6.3 Prior to use, welding consumables should be dried and/or baked in accordance with the consumable manufacturer's recommendations. The condition of welding consumables shall be subject to regular inspections.

2.6.4 All welders and welding operators are to be suitably skilled and qualified for the type of welding work to be undertaken.

2.6.5 Welding procedures are to be established for all welds joining pressure containing parts and for welds made directly onto pressure containing parts.

2.6.6 Welding should be performed wherever possible in covered workshops. Where this is not possible, provision is to be made in the welding area to give adequate protection from wind, rain and cold, etc.

2.6.7 Surfaces of all parts to be welded are to be clean, dry and free from rust, scale and grease. Where prefabrication primers are applied over areas which will be subsequently welded, they are to be approved for that application.

2.6.8 Preheat shall be applied, as specified in the approved welding procedure, for a distance of at least 75 mm from the joint preparation edges. The method of application and temperature control are to be such as to maintain the required level during welding and is to be to the satisfaction of the Surveyors.

2.6.9 When the ambient temperature is 0°C or less, or where moisture resides on the surfaces to be welded, due care should be taken to pre-warm and dry the weld joint.

2.6.10 The welding arc is to be struck on the parent metal which forms part of the weld joint or on previously deposited weld metal.

2.6.11 Tack welds made in the root of the weld joint are to be removed in the process of welding the seam.

2.6.12 Where the welding process used is slag forming (e.g. manual metal arc, submerged arc, etc.) each run of deposit is to be cleaned and free from slag before the next run is applied.

2.6.13 Wherever possible, full penetration welds are to be made from both sides of the joint. Prior to welding the second side, the weld root is to be cleaned, in accordance with the requirements of the approved welding procedure, to ensure freedom from defects. When air-arc gouging is used, care is to be taken to ensure that the ensuing groove is slag and oxide free and has a profile suitable for welding.

2.6.14 After welding has been stopped for any reason, care is to be taken in restarting to ensure that the previously deposited weld metal is thoroughly cleaned of slag and debris, and preheat has been re-established.

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2.6.15 Where welding from one side only cannot be avoided, care is to be exercised to ensure the root gap is in accordance with the approved welding procedure and the root is properly fused.

2.6.16 Steel backing strips may be used for the circumferential seams of Class 2/1, Class 2/2 and Class 3 pressure vessels and are to be the same nominal composition as the plates to be welded.

2.6.17 Fillet welds are to be made to ensure proper fusion and penetration at the root of the fillet. At least two layers of weld metal are to be deposited at each weld affixing branch pipes, flanges and seatings.

2.6.18 Where attachment of lugs, brackets, branches, manhole frames, reinforcement plates and other members are to be made to the main pressure shell by welding, these shall be to the same standard as that required for the main vessel shell construction.

2.6.19 The attachment by welding of such fittings to the main pressure shell after post-weld heat treatment is not permitted.

2.6.20 Completed welds shall be at least flush with the surface of the plates joined and have the shape and size specified in the approved drawings or specifications. Welds shall have an even contour and blend smoothly with the base materials. Maximum sizes of weld reinforcement in accordance with a recognized Pressure Vessel Code or Standard will be accepted.

2.6.21 The main weld seams and all welded attachments made to pressure containing parts are to be completed prior to post weld heat treatment. Tubes that have been expanded into headers or drums may be seal welded without further post weld heat treatment.

2.6.22 The finish of welds attaching pressure parts and non-pressure parts to the main pressure shell is to be such as to allow satisfactory examination of the welds. In the case of Class 1 and Class 2/1 pressure vessels, these welds are to be ground smooth, if necessary, to provide a suitable finish for examination.

2.6.23 All lugs, brackets, branches, manhole frames and reinforcements around openings and other members are to conform to the shape of the surface to which they are attached.

2.7 Tolerances for cylindrical shells

2.7.1 Measurements are to be made to the surface of the parent plate and not to a weld, fitting or other raised part.

2.7.2 In assessing the out-of-roundness of pressure vessels, the difference between the maximum and minimum internal diameters measured at one cross-section is not to exceed the amount given in Table 14.2.1.

Table 14.2.1 Tolerances for cylindrical shells

Nominal internal diameter of vessel in mm	Difference between maximum and minimum diameters	Maximum departure from designed form
≤ 300 > 300 ≤ 460 > 460 ≤ 600 > 600 ≤ 900 > 900 ≤ 1200 > 1220 ≤ 1520 > 1520 ≤ 1900	1 % of internal diameter	1,2 mm 1,6 mm 2,4 mm 3,2 mm 4,0 mm 4,8 mm 5,6 mm
> 1900 ≤ 2300 > 2300 ≤ 2670 > 2670 ≤ 3950	19 mm	6,4 mm 7,2 mm 8,0 mm
> 3950 ≤ 4650 > 4650	19 mm 0,4 % of internal diameter	0,2 % of internal diameter

2.7.3 The profile measured on the inside or outside of the shell, by means of a gauge of the designed form of the shell, and having a chord length equal to one-quarter of the internal diameter of the vessel, is not to depart from the designed form by more than the amount given in Table 14.2.1. This amount corresponds to *x* in Fig. 14.2.1.

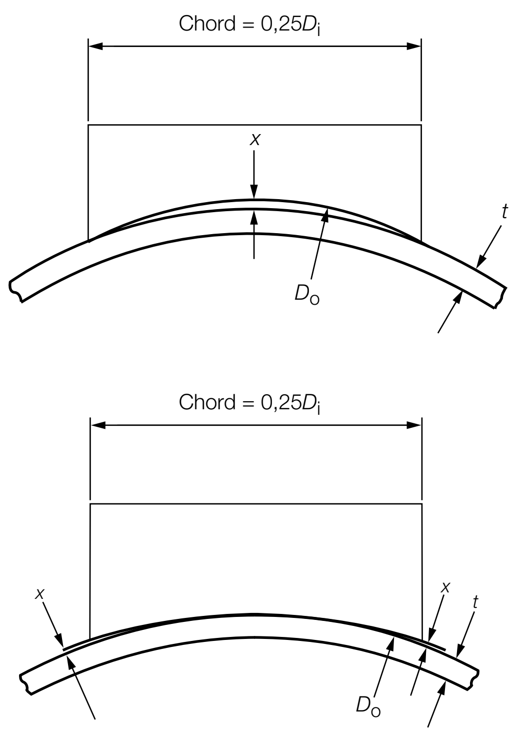

Fig. 14.2.1 Tolerances for cylindrical shells

2.7.4 Shell sections are to be measured for out-of-roundness, either when laid flat on their sides or when set up on end. When the shell sections are checked while lying on their sides, each measurement for diameter is to be repeated after turning the shell through 90° about its longitudinal axis. The two measurements for each diameter are to be averaged, and the amount of out-of-roundness calculated from the average values so determined.

2.7.5 Where there is any local departure from circularity due to the presence of flats or peaks at welded seams, the departure from designed form shall not exceed that of Table 14.2.1.

2.7.6 The external circumference of the completed shell is not to depart from the calculated circumference (based upon nominal inside diameter and the actual plate thickness) by more than the amounts given in Table 14.2.2.

Table 14.2.2 Circumferential tolerances

Outside diameter (nominal inside diameter plus twice actual plate thicknes), in mm	Circumferential tolerance
300 to 600 inclusive	±5 mm
Greater than 600	±0,25 per cent

■ *Section 3* Routine weld tests for pressure vessels

3.1 General requirements for routine weld tests

3.1.1 Routine or production weld tests are specified as a means of monitoring the quality of the welded joints and are required for pressure vessel Classes 1, 2/1 and 2/2.

3.1.2 Routine test plates are required during the manufacture of vessels and as part of the initial approval test programme for Class 1 vessel manufacturers, refer to MQPS 0-4.

3.1.3 Routine weld tests are not required for Class 3 pressure vessels unless the minimum design temperature is below minus 10°C. However, occasional check tests may be requested at the discretion of the Surveyors.

3.1.4 Routine test plates are not required for circumferential seams of cylindrical pressure vessels. Spherical vessels are to have one test plate prepared having a welded joint which is a simulation of the circumferential seams.

3.1.5 In addition, routine weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

3.2 Test plate requirements

3.2.1 Test plates, of sufficient dimensions to provide one complete set of specimens, are to be prepared for each vessel and are to be welded as a continuation and simulation of the longitudinal weld joint.

3.2.2 For Class 2/2 vessels, where a large number are made concurrently at the same works using the same welding procedure and the plate thicknesses do not vary by more than 5 mm, one test may be performed for each 37 m of longitudinal plus circumferential weld seam with the agreement of the Surveyor. In these cases, the thickness of the test plate is to be equal to the thickest shell plate used in the construction.

3.2.3 Where the vessel size or design results in a small number of longitudinal weld seams, with the agreement of the Surveyors, one test plate may be prepared for testing, provided that the welding details are the same for each seam.

3.2.4 Test plate materials shall be of the same grade, thickness and supply condition and from the same cast as that of the vessel shell. The test plate shall be welded at the same time as the vessel weld to which it relates and is to be supported so that distortion during welding is minimized.

3.2.5 Where there is a requirement for several routine tests to be welded, welding is to be performed by different welders, wherever possible.

3.2.6 The test assembly may be detached from the vessel weld only after the Surveyor has performed a visual examination and has added his mark or stamp. Straightening of test weld prior to mechanical testing is not permitted.

3.2.7 Where the pressure vessel is required to be subjected to post-weld heat treatment, the test weld shall be heat treated, after welding, in accordance with the same requirements. Subject to agreement with the Surveyor this may be performed separately from the vessel.

3.3 Inspection and testing

3.3.1 The test weld is to be subjected to the type of non-destructive examination and acceptance criteria as specified for the weld seam to which the test relates. Non-destructive examination shall be performed prior to removing specimens for mechanical testing, but after any post-weld heat treatment.

3.3.2 The test weld is to be sectioned to remove the number and type of test specimens for mechanical testing as follows.

3.4 Mechanical testing requirements

3.4.1 The test plates are to be machined to provide the following test specimens:

(a) Tensile.
(b) Bend.
(c) Hardness.
(d) Impact, *see* Table 14.3.1.
(e) Macrograph and hardness survey of full weld section.

Table 14.3.1 Impact test requirements

Pressure vessel Class	Minimum design temperature	Plate material thickness, *t*, in mm	Impact test temperature
Class 1	–10°C or above	All	5°C below the minimum design temperature or 20°C whichever is the lower
All Classes	Below –10°C	$t \leq 20$	5°C below the minimum design temperature
		$20 < t \leq 40$	10°C below the minimum design temperature
		$t > 40$	Subject to agreement

3.4.2 One set of specimens for mechanical testing is to be removed, as shown in Fig. 14.3.1 or Fig. 14.3.2, as appropriate for the Class of approval. Impact tests shall be removed and tested where required by Table 14.3.1.

3.4.3 **Longitudinal tensile test for weld metal**. An all weld metal longitudinal tensile test is required and, for thicknesses in excess of 20 mm where more than one welding process or type of consumable has been used to complete the joint, additional longitudinal tests are required from the respective area of the weld. This does not apply to thse welding process or consumables used solely to deposit the root weld. Specimens shall be tested in accordance with the following requirements:

(a) The diameter and gauge length of the test specimen shall be in accordance with Fig. 11.2.1 in Chapter 11 of the Rules for Materials.

(b) For carbon steels, the tensile strength of the weld metal is to be not less than the minimum specified for the plate material and not more than 145 N/mm^2 above this value. The percentage elongation, A, is to be not less than that given by:

$$A = \frac{(980 - R)}{21,6}$$

where

R is the tensile strength, in N/mm^2, obtained from the all weld metal tensile test.

In addition, this elongation is to be not less than 80 per cent of the minimum elongation specified for the plate.

(c) For other materials, the tensile strength and percentage elongation shall not be less than that specified for the base materials welded.

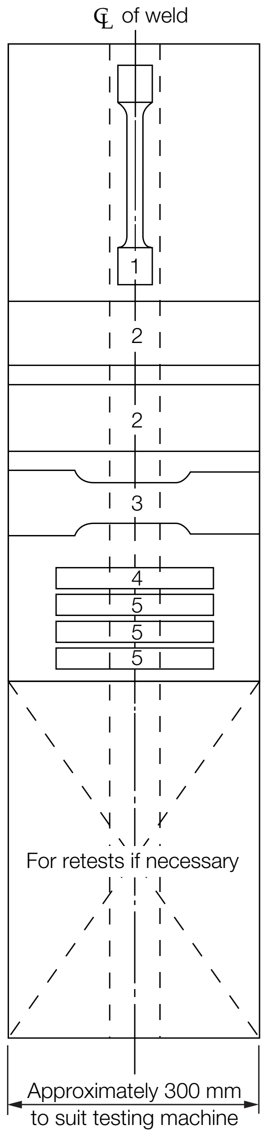

Fig. 14.3.1
Routine test plate – Test specimens for Class 1 and 2/1

1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joints.
4. Macro-test specimen.
5. Charpy V-notch impact test specimens.
(For all Class 1 pressure vessels and other Classes of pressure vessels where the minimum design temperature is below –10°C).

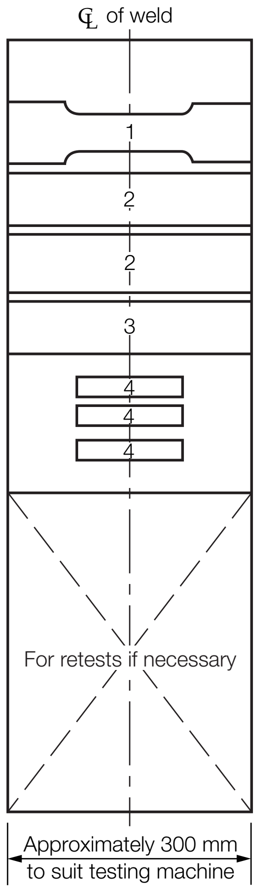

Fig. 14.3.2
Routine test plate – Test specimens for Class 2/2

1. Tensile test for joints.
2. Bend test specimens.
3. Macro-test specimen.
4. Charpy V-notch impact test specimens (if required by Table 14.3.1).

3.4.4 **Transverse tensile test for joint**. For the transverse tensile test, the weld reinforcement is to be removed, and shall meet the following requirements:

(a) One reduced section tensile test specimen is to be cut transversely to the weld in accordance with the dimensions shown in Fig. 11.2.2 in Chapter 11 of the Rules for Materials.
(b) In general, where the plate thickness exceeds 30 mm, or where the capacity of the tensile test machine prevents full thickness tests, each tensile test may be made up of several reduced section specimens, provided that the whole thickness of the weld is subjected to testing.
(c) The tensile strength obtained is to be not less than the minimum specified tensile strength for the plate material, and the location of the fracture is to be reported.

3.4.5 **Transverse bend test**. The bend test specimens shall meet the following:

(a) Four bend test specimens of rectangular section are to be cut from the test plate transversely to the weld, two bent with the outer surface of the weld in tension (face bend), and the other two with the inner surface in tension (root bend).
(b) The specimens are to be in accordance with Ch 11,2.1.3 of the Rules for Materials.
(c) Each specimen is to be mounted on roller supports with the centre of the weld midway between the supports. The plunger shall have the diameter shown in Table 14.3.2 based on the specimen thickness, *t*.
(d) After bending through an angle of at least 120°, there is to be no crack or defect exceeding 1,5 mm measured across the specimen or 3 mm measured along the specimen. Premature failure at the edges of the specimen should not be cause for rejection, unless this is associated with a weld defect.

Table 14.3.2 Bend test requirements

Material grade	Former diameter
Up to Grade 460	$3t$
490 and 510	$4t$
13Cr Mo 45	$5t$
11Cr Mo 910	$5t$
Other materials	Subject to agreement

where
t is the thickness of the bend test specimen.

3.4.6 **Macro-specimen and hardness survey**. A macro examination specimen is to be removed from the test plate near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone. The specimen is to be prepared and examined in accordance with the following:

(a) The cross-section of the specimen is to be ground, polished and etched to clearly reveal the weld runs, and the heat affected zones.
(b) The specimen shall show an even weld profile that blends smoothly with the base material and have satisfactory penetration and fusion, and an absence of significant inclusions or other defects.
(c) Should there be any doubt as to the condition of the weld as shown by macro-etching, the area concerned is to be microscopically examined.
(d) For carbon, carbon manganese and low alloy steels, a hardness survey is to be performed on the macro specimen using either a 5 kg or 10 kg load, testing is to include the base material, the weld and the heat affected zone. Hardness scans on the cross-section are to be performed in the cap weld areas within 2 mm of the weld surface. The maximum recorded hardness shall not exceed 350 Hv10.

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3.4.7 **Charpy V-notch impact test**. Charpy V-notch impact test specimens are to be prepared for testing when required by Table 14.3.1. Tests are to be performed and satisfy the following requirements:

(a) Each test is to consist of a set of three Charpy V-notch impact specimens and are to be removed with the vee notch perpendicular to the plate surface.
(b) The dimensions and tolerances of the specimens are to be in accordance with Chapter 2 of the Rules for Materials.
(c) Specimens are to be removed for testing from the weld centreline and the heat affected zone (fusion line and fusion line + 2 mm locations). Heat affected zone impact tests may be omitted where the minimum design temperature is above +20°C.
(d) For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, impact tests are required from the respective area of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld.
(e) The average energy of a set of three specimens is not to be less than 27Joules or the minimum specified for the base material, whichever is the higher. The minimum energy for each individual specimen is to meet the requirements of Ch 1,4.5.2 of the Rules for Materials.

3.5 Failure to meet requirements

3.5.1 If any test specimen fails to meet the requirements, additional specimens may be removed and tested in accordance with Ch 1,4.6 of the Rules for Materials.

3.5.2 Where a routine weld test fails to meet requirements, the welds to which it relates will be considered as not having met the requirements. The reason for the failure is to be established and the manufacturer is to take such steps as necessary to either:

(a) Remove the affected welds and have them re-welded to the Surveyor's satisfaction, or
(b) demonstrate that the affected production welds have acceptable properties.

■ *Section 4*
Repairs to welds on fusion welded pressure vessels

4.1 General

4.1.1 Where non-destructive examinations reveal unacceptable defects in the welded seams, they are to be repaired in accordance with the following:

(a) Major repairs shall not be carried out without the prior consent of the Surveyors.
(b) Where cracks have developed as a result of welding, these are to be reported to the Surveyors and the cause established prior to undertaking weld repair.
(c) Defects may be removed by grinding, chipping or thermal gouging. Where thermal gouging is used, the repair groove shall be subsequently ground to remove oxides and debris. In all cases, the groove shall have a profile suitable for welding.
(d) Prior to commencing repair welding, confirmation that the original defect has been removed is required by performing visual examination. This may be augmented by surface crack detection examination at the discretion of the Surveyors.
(e) Repair welding is to be performed using welding procedures agreed with the Surveyors.
(f) Where the pressure vessel requires post weld heat treatment in accordance with Section 5, this shall be performed after completion of the weld repairs.
(g) Weld repairs are to be shown by further non-destructive examinations to have removed the defect to the Surveyor's satisfaction.

4.2 Re-repairs

4.2.1 In general, only two repair attempts are to be made of the same defect. Any subsequent repairs will be at the discretion of the Surveyors and may require the removal of the heat affected zone of the original repair.

■ *Section 5*
Post-weld heat treatment of pressure vessels

5.1 General

5.1.1 Fusion welded pressure vessels, where indicated in Table 14.5.1, are to be heat treated on completion of the welding of the seams and of all attachments to the shell and ends, and before the hydraulic test is carried out.

5.1.2 Tubes which have been expanded into headers or drums may be seal welded without further post weld heat treatment.

5.1.3 Where the weld connects parts of different thicknesses, the thickness to be used when applying the requirements for post weld heat treatment is to be either the thinner of the two plates for butt welded connections, or the thickness of the shell for connections to flanges, tubeplates and similar connections.

5.1.4 Parts are to be properly prepared for heat treatment, sufficient temporary supports are to be provided to prevent undue distortion or collapse of the structure and any machined faces are to be adequately protected against scaling.

5.1.5 Care is to be exercised to provide drilled holes in double reinforcing plates and other closed spaces prior to heat treatment.

Table 14.5.1 Post-weld heat treatment requirements

Type of steel	Plate thickness above which post weld heat treatment (PWHT) is required	
	Steam raising plant	Other pressure vessels
Carbon and carbon/manganese steels without low temperature impact values	20 mm	30 mm
Carbon and carbon/manganese steels with low temperature impact values	20 mm	40 mm
1Cr $^{1}/_{2}$Mo	All thicknesses	All thicknesses
2$^{1}/_{4}$Cr 1Mo	All thicknesses	All thicknesses
$^{1}/_{2}$Cr $^{1}/_{2}$Mo $^{1}/_{4}$V	All thicknesses	All thicknesses
Other alloy steels	Subject to special consideration.	

5.2 Basic requirements for heat treatment of fusion welded pressure vessels

5.2.1 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained.

5.2.2 The heat treatment facilities shall be capable of controlling the temperature throughout the heat treatment cycle and adequate means of measuring and recording the vessel temperature are to be provided. To this end, thermo-couples are to be attached such that they are in contact with the vessel.

5.2.3 Unless stated otherwise, post weld heat treatment is to be carried out by means of slow, even heating from 300°C to the soak temperature, holding within the prescribed soaking temperature range for the time specified (usually one hour per 25 mm of weld thickness), followed by slow even cooling to 300°C.

5.2.4 Recommended soaking temperatures and periods are given in Table 14.5.2 for different materials. Where other materials are used for pressure vessel construction, full details of the proposed heat treatment are to be submitted for consideration.

5.2.5 Where pressure vessels are of such dimensions that the whole length cannot be accommodated in the furnace at one time, the pressure vessels may be heated in sections, provided that sufficient overlap is allowed to ensure the heat treatment of the entire length of the longitudinal seam.

5.2.6 Where it is proposed to adopt special methods of heat treatment, full particulars are to be submitted for consideration. In such cases it may be necessary to carry out tests to show the effect of the proposed heat treatment.

Table 14.5.2 Post-weld soak temperatures and times

Material type	Soak temperature, °C (*see* Note)	Soak period
Carbon and carbon/manganese grades:	580–620°	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr $^{1}/_{2}$Mo	620–660°	1 hour per 25 mm of thickness, minimum of 1 hour
2$^{1}/_{4}$Cr 1Mo	650–690°	1 hour per 25mm of thickness, minimum of 1 hour
$^{1}/_{2}$Cr $^{1}/_{2}$Mo $^{1}/_{4}$V	670–720°	1 hour per 25mm of thickness, minimum of 1 hour
NOTE For materials supplied in the tempered condition, the post weld soak temperature shall be lower than the material tempering temperature.		

■ *Section 6* Welded pressure pipes

6.1 General

6.1.1 Fabrication of pipework is to be carried out in accordance with the requirements of this Section unless other more stringent requirements have been specified.

6.1.2 Piping systems are to be constructed in accordance with approved plans and specifications.

6.1.3 Pipe welding may be performed using manual, semi-automatic or fully-automatic electric arc welding processes. The use of oxy-acetylene welding will be limited to Class III pipework in carbon steel material that is not carrying flammable fluids and limited to butt joints in pipes not exceeding 100 mm diameter or 9,5 mm wall thickness.

6.2 Fit-up and alignment

6.2.1 Acceptable methods of flange attachment are illustrated in Fig. 10.2.1 in Chapter 10. If backing rings are used with flange type (a) then they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes.

Requirements for Fusion Welding of Pressure Vessels and Piping

6 2.2 Alignment of pipe butt welds shall be in accordance with Table 14.6.1. Where fusible inserts are used, the alignment shall be within 0,5 mm in all cases.

Table 14.6.1 Pipe alignment tolerances

Pipe size	Maximum permitted mis-alignment
$D < 150\phi$ mm and $t \leq 6$ mm	1 mm or 25% of *t*, whichever is the lesser
$D < 300\phi$ mm and $t \leq 9{,}5$ mm	1,5 mm or 25% of *t*, whichever is the lesser
$D \geq 300$ and $t > 9{,}5$ mm	2 mm or 25% of *t*, whichever is the lesser
D =pipe internal diameter t =pipe wall thickness	

6.2.3 Where socket welded fittings are employed, they are to comply with the requirements of Ch 10,2.7. The diametrical clearance between the outside diameter of the pipe and the bore of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the bottom of the socket.

6.3 Welding workmanship

6.3.1 Welding procedures are to be established for welding of pipework including attachment welds directly to pressure retaining parts and are to be qualified by testing on simulated joints.

6.3.2 Where the work requires a significant number of branch connections, tests may also be required to demonstrate that the type of joint(s) and welding techniques employed are capable of achieving the required quality.

6.3.3 Welding consumables and, where used, fusible root inserts, are to be suitable for the materials being joined.

6.3.4 For welding of carbon and low alloy steels, preheat is to be applied depending on the material grade, thickness and hydrogen grading of the welding consumable in accordance with Table 14.6.2 unless welding procedure testing indicates that higher levels are required.

6.3.5 Preheating is to be effected by a method which ensures uniformity of temperature at the joint. The method of heating and the means adopted for temperature control are to be to the satisfaction of the Surveyors.

6.3.6 All welding is to be performed in accordance with the approved welding procedures, *see* 6.3.1, by welders who are qualified for the materials, joint types and welding processes employed.

6.3.7 Welding without filler metal is generally not permitted for welding of duplex stainless steel materials.

Table 14.6.2 Minimum preheat requirements

Material grade	Thickness *t*, in mm (4)	Minimum preheat temperature (1), °C	
		Non-low H_2	Low H_2 (2)
Carbon and carbon/manganese grades: 320 and 360	$t \leq 10$ $t \geq 20$	50 100	10 50
Carbon and carbon/manganese grades: 410, 460 and 490	$t \leq 10$ $t \geq 20$	75 150	20 100
1Cr 1/2Mo	$t < 13$ $t \geq 13$	(3)	100 150
2 1/4Cr 1Mo	$t < 13$ $t \geq 13$	(3)	150 200
1/2Cr 1/2Mo 1/4V	$t < 13$ $t \geq 13$	(3)	150 200

NOTES
1. For thicknesses up to 6 mm, the preheat levels specified may be reduced subject to satisfactory hardness testing during welding procedure qualification.
   In all cases where the ambient temperature is 0°C or below, preheat is required.
2. Low hydrogen process or consumables are those which have been tested and have achieved a grading of H15 or better, *see* Chapter 11 of the Rules for Materials.
3. Low hydrogen process is required for these materials.
4. t = the thickness of the thicker member.

6.3.8 All welds in high pressure and high temperature pipelines are to have a smooth surface finish and even contour; if necessary, they are to be made smooth by grinding.

6.3.9 Check tests of the quality of the welding are to be carried out periodically at the discretion of the Surveyors.

6.4 Heat treatment after bending of pipes

6.4.1 Heat treatment should be carried out in a suitable furnace provided with temperature recording equipment in accordance with 5.2.

6.4.2 Hot forming should generally be carried out within the normalizing temperature range. When carried out within this temperature range, no subsequent heat treatment is required for carbon and carbon/manganese steels. For alloy steels, 1Cr 1/2Mo, 2 1/4Cr 1Mo and 1/2Cr 1/2Mo 1/4V, a subsequent stress relieving heat treatment in accordance with Table 14.5.2 is required irrespective of material thickness.

6.4.3 When hot forming is performed outside the normalizing temperature range, a subsequent heat treatment in accordance with Table 14.6.3 is required.

Table 14.6.3 Heat treatment after forming of pipes

Type of steel	Heat treatment required
Carbon and carbon/manganese: Grades 320, 360, 410, 460 and 490	Normalize at 880 to 940°C
1Cr $^1/_2$Mo	Normalize at 900 to 960°C, followed by Tempering at 640 to 720°C
2$^1/_4$Cr 1Mo	Normalize at 900 to 960°C, followed by Tempering at 650 to 780°C
$^1/_2$Cr $^1/_2$Mo $^1/_4$V	Normalize at 930 to 980°C, followed by Tempering at 670 to 720°C
Other alloy steels	Subject to special consideration

6.4.4 After cold forming to a radius measured at the centreline of the pipe of less than four times the outside diameter, heat treatment in accordance with Table 14.6.3 is required.

6.4.5 The heat treatments specified above shall be applied unless the pipe material manufacturer specifies or recommends other requirements.

6.4.6 Bending procedures and subsequent heat treatment for other alloy steels will be subject to special consideration.

6.5 Post-weld heat treatment of pipe welds

6.5.1 Post-weld heat treatment shall be carried out in accordance with the general requirements specified in 5.2 for pressure vessels.

6.5.2 Post-weld heat treatment is to be performed on steel pipes and fabricated branch pieces on completion of welding where the material thickness exceeds that specified in Table 14.6.4.

6.5.3 Recommended soaking temperatures and periods for post-weld heat treatment are given in Table 14.5.2.

6.5.4 Where oxy-acetylene welding has been used, due consideration should be given to the need for normalizing and tempering after such welding.

Table 14.6.4 Thickness limits for post-weld heat treatment of pipe welds

Type of steel	Requirements for heat treatment
Carbon and carbon/manganese: Grades 320, 360, 410, 460 and 490	Thicknesses exceeding 30 mm
1Cr $^1/_2$Mo	Thicknesses exceeding 8 mm
2$^1/_4$Cr 1Mo	All thicknesses
$^1/_2$Cr $^1/_2$Mo $^1/_4$V	All thicknesses
Other alloy steels	Subject to special consideration

■ *Section 7*
Non-Destructive Examination

7.1 General

7.1.1 Non-Destructive Examinations (NDE) of pressure vessel welds are to be carried out in accordance with a nationally recognized code or standard.

7.1.2 NDE should not be applied until an interval of at least 48 hours has elapsed since the completion of welding.

7.2 NDE personnel

7.2.1 NDE Personnel are to be qualified to an appropriate level of a nationally recognized certification scheme.

7.2.2 Generally, operators subject to direct supervision are to be qualified to Level I, unsupervised personnel to Level II and more senior personnel to Level III.

7.2.3 Qualification schemes are to include assessments of practical ability for Levels I and II individuals; these examinations to be made on representative test pieces containing relevant defects.

7.3 Extent of NDE

7.3.1 For Class 1 pressure vessels:

(a) All butt welded seams in drums, shells, headers and test plates, together with tubes or nozzles over 170 mm outside diameter are subject to 100 per cent volumetric and surface crack detection inspections.

(b) For circumferential butt welds in extruded connections, tubes, headers and other tubular parts of 170 mm outside diameter or less, at least 10 per cent of the total number of welds is to be subjected to volumetricexamination and surface crack detection inspections.

7.3.2 For Class 2/1 pressure vessels, volumetric and surface crack detection inspections are to be applied at selected regions of each main seam. At least 10 per cent of each main seam is to be examined together with the full length of each welded test plate. When an unacceptable indication is detected, at least two additional check points in the seam are to be selected by the surveyor for examination using the same inspection method. If further unacceptable defects are found then either:

(a) The whole length of weld represented is to be cut out and re-welded and re-examined as if it was a new weld with the test plates being similarly treated; or
(b) The whole length of the weld represented is to be re-examined using the same inspection methods.

7.3.3 Butt welds in Class I pipes of 75mm or more outside diameter are subject to 100 per cent volumetric and surface crack detection inspections. The extent and method of testing applied to butt welds in Class I pipes of less than 75 mm outside diameter is at the Surveyor's discretion.

7.3.4 The extent of testing to be applied to butt welds or fillet welds in Class II pipes of 100 mm or more outside diameter is at the Surveyor's discretion.

7.3.5 NDE is not required for Class II pipes less than 100 mm outside diameter.

7.4 Procedures

7.4.1 Non Destructive Examinations are to be made in accordance with a definitive written procedure prepared in accordance with a nationally recognized standard and endorsed by a Level III individual. As a minimum, the procedure will identify personnel qualification levels, NDE datum and identification system, extent of testing, methods to be applied with technique sheets, acceptance criteria and reporting requirements.

7.5 Method

7.5.1 Volumetric examinations may be made by radiography or, in the case of welds of nominal thickness 15 mm or above, by ultrasonic testing. The preferred method for surface crack detection in ferrous metals is magnetic particle inspection, and that for non-magnetic materials is liquid penetrant inspection.

7.6 Repairs

7.6.1 Unacceptable defects are to be repaired and re-examined using the NDE methods originally applied.

7.7 Evaluation and reports

7.7.1 The manufacturer shall be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance or otherwise with the criteria established in the inspection procedure are to be issued. Reports are to include the following information where appropriate:

(a) Date of inspection;
(b) Names, qualifications and signatures of operator and supervisor;
(c) Component identification;
(d) Location and extent of testing;
(e) Heat treatment status;
(f) Weld type, procedure and configuration;
(g) Surface condition;
(h) Inspection procedure reference;
(j) Equipment used;
(k) Results showing size, position and nature of any defects repaired; and
(l) Statement of final acceptability to established criteria.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to the design and construction of steering gear.

1.1.2 The requirements of this Chapter are based on the assumption of heavy traffic on relatively narrow waterways through densely populated areas. When ships are intended to be used on waterways with service conditions different from this, they will receive special consideration.

1.1.3 Attention is also drawn to additional requirements of National or International Authorities, e.g. the Rules issued by the Central Rhine Commission.

1.1.4 Consideration will be given to other cases, or to arrangements which are equivalent to those required by the Rules.

■ *Cross-references*

For azimuth or rotatable thruster units, *see* Chapter 16.
For bow thruster units intended for manoeuvring, *see* Chapter 17.
For general piping requirements, *see* Chapters 10, 11 and 12.

1.2 Definitions

1.2.1 **Steering gear control system** means the equipment by which orders are transmitted from the wheel house to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.2.2 **Main steering gear** means the machinery, rudder actuator(s), the steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder-stock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

1.2.3 **Steering gear power unit** means:
(a) In the case of electric steering gear, an electric motor and its associated electrical equipment;
(b) In the case of electro hydraulic steering gear, an electric motor and its associated electrical equipment and connected pump;
(c) In the case of other hydraulic steering gear, a driving engine and connected pump.

1.2.4 **Auxiliary steering gear** means the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.2.5 **Power actuating system** means the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller quadrant and rudder stock, or components serving the same purpose.

1.2.6 **Maximum ahead service speed** means the maximum service speed which the ship is designed to maintain, at maximum loaded draught, at maximum propeller RPM and corresponding engine MCR.

1.2.7 **Rudder actuator** means the components which converts directly hydraulic pressure into mechanical action to move the rudder.

1.2.8 **Maximum working pressure** means the maximum expected pressure in the system when the steering gear is operated to comply with 2.1.2.

1.3 General

1.3.1 The steering gear is to be secured to the seating by fitted bolts, and suitable chocking arrangements are to be provided. The seating is to be of substantial construction.

1.3.2 The steering gear compartment is to be readily accessible and, as far as practicable, separated from machinery spaces.

1.4 Plans

1.4.1 Before starting construction, the steering gear machinery plans, specifications and calculations are to be submitted. The plans are to give:
(a) Details of scantlings and materials of all load bearing and torque transmitting components and hydraulic pressure retaining parts together with proposed rated torque and all relief valve settings.
(b) Schematic of the hydraulic system(s), together with pipe material, relief valves and working pressures.
(c) Details of control and electrical aspects.

1.5 Materials

1.5.1 All the steering gear components and the rudder stock are to be of sound reliable construction to the Surveyor's satisfaction.

1.5.2 All components transmitting mechanical forces to the rudder stock are to be tested according to the requirements of the *Rules for the Manufacture, Testing and Certification of Materials.*

1.5.3 All steering unit components transmitting mechanical forces are to be of steel or other approved ductile material. In general, such material is to have an elongation of not less than 12 per cent nor a tensile strength in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for low pressure valve bodies and mechanical parts with low stress levels.

1.5.4 Where appropriate, consideration will be given to the acceptance of non-ferrous material.

1.6 Rudder, rudder stock, tiller and quadrant

1.6.1 For the requirements of rudder and rudder stock, *see* Pt 3, Ch 12,2.

1.6.2 For the requirements of tillers and quadrants including the tiller to stock connection, *see* Table 15.1.1.

1.6.3 An efficient locking or brake arrangement is to be fitted to all gears to keep the rudder steady when necessary. In the case of hydraulic steering gears which are fitted with isolating valves on the body of the gear and duplicate power units, an additional mechanical brake need not be fitted.

1.6.4 In bow rudders having a vertical locking pin operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

1.6.5 The factor of safety against slippage, *S* (i.e. for torque transmission by friction) is generally based on

$$S = \frac{\text{The torque transmissible by friction}}{M}$$

where *M* is the maximum torque at the relief valve pressure which is generally equal to the design torque as specified by the steering gear manufacturer.

1.6.6 For conical sections, *S* is based on the following equation:

$$S = \frac{\mu A \sigma_r}{\sqrt{(W + A \sigma_r \theta)^2 + Q^2}}$$

where

A = interfacial surface area, in mm^2

W = weight of rudder and stock, if applicable, when tending to separate the fit, in N

Q = shear force = $\frac{2M}{d_m}$ in N

where

d_m = in mm, is the mean contact diameter of tiller/stock interface and *M,* in N/mm, is defined in 1.6.5

Q = cone taper half angle in radians (e.g. for cone taper 1:10, Q = 0,05)

m = coefficient of friction

σ_r = radial interfacial pressure or grip stress, in N/mm^2.

1.6.7 On double rudder installations, where the two tillers are connected by mechanical means (tie-bar), the strength and stability of the tie-bar is to be assessed using the maximum steering torque applied to the stock.

1.6.8 Where higher tensile steel bolts are used on bolted tillers and quadrants, the yield and ultimate tensile stresses of the bolt material are to be stated on plans submitted for approval, together with full details of the methods to be adopted to obtain the required setting-up stress. Where proprietary nuts or systems are used, the manufacturer's instructions for assembly are to be adhered to.

Table 15.1.1 Connection of tiller to stock (*see continuation*)

Item	Requirements
(1) Dry fit – tiller to stock, *see also* 1.6.5 and 1.6.6	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,17 (d) Grip stress not to be less than 20 N/mm^2
(2) Hydraulic fit – tiller to stock, *see also* 1.6.5 and 1.6.6	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,14 (d) Grip stress not to be less than 20 N/mm^2
(3) Ring locking assemblies fit-tiller to stock, *see also* 1.6.5	(a) Factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress (b) Coefficient of friction = 0,12 (c) Grip stress not to be less than 20 N/mm^2
(4) Bolted tiller and quadrant	Shim to be fitted between two halves before machining to take rudder stock, then removed prior to fitting Minimum thickness of shim, For 4 connecting bolts: $t_s = 0{,}0014\delta_{su}$ mm For 6 connecting bolts: $t_s = 0{,}0012\delta_{su}$ mm Key(s) to be fitted Diameter of bolts, $d_{tb} = \dfrac{0{,}60\delta_{su}}{\sqrt{n_{tb}}}$ mm A predetermined setting-up load equivalent to a stress of a pproximately 0,7 of the yield strength of the bolt material should be applied to each bolt on assembly. A lower stress may be accepted provided that two keys, complying with item (5), are fitted. Distance from centre of stock to centre of bolts should generally be equal to $\delta_{su}\left(1{,}0 + \dfrac{0{,}3}{\sqrt{n_{tb}}}\right)$ mm Thickness of flange on each half of the bolted tiller $\geq \dfrac{0{,}66\delta_{su}}{\sqrt{n_{tb}}}$ mm
(5) Key/keyway	Effective sectional area of key in shear ≥ $0{,}25\delta_{su}^2$ mm^2 Key thickness ≥ $0{,}17\delta_{su}$ mm Keyway is to extend over full depth of tiller and is to have a rounded end. Keyway root fillets are to be provided with suitable radii to avoid high local stress
(6) Section modulus – tiller arm (at any point within its length about vertical axis)	To be not less than the greater of: (a) $Z_{TA} = \dfrac{0{,}21\delta_{su}^3 (b_T - b_s)}{1000 b_T}$ cm^3 (b) $Z_{TA} = \dfrac{0{,}083\delta_{su}^3 (b_T - 0{,}9 b_s)}{1000 b_T}$ cm^3 If more than one arm fitted, combined modulus is to be not less than the greater of (a) or (b) For solid tillers, the breadth to depth ratio is not to exceed 4
(7) Boss	Depth of boss ≥ δ_{su} mm Thickness of boss in way of tiller, irrespective of the keyway: ≥ $0{,}4\delta_{su}$ mm

Table 15.1.1 Connection of tiller to stock (*conclusion*)

Symbols		
b_s	=	distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm NOTE: b_T and b_s are to be measured with zero rudder angle
b_T	=	distance from the point of application of the load on the tiller to the centre of the rudder stock, in mm
n_{tb}	=	number of bolts in the connection flanges, but generally not to be taken greater than six
t_s	=	thickness of shim for machining bolted tillers and quadrants, in mm
Z_{TA}	=	section modulus of tiller arm, in cm^3
δ_{su}	=	rule rudderstock diameter in way of tiller, *see* Table 12.2.1 in Pt 3, Ch 12 For high tensile steel, a material factor ko may be applied as follows: $k_0 = \sqrt[4]{\left(\frac{235}{\sigma_o}\right)^3}$ where σ_o = the Yield stress of the material limited to 70 per cent of the UTS or 450 N/mm^2 whichever is the lesser
d_{tb}	=	diameter of bolts securing bolted tillers and quadrants, in mm

■ *Section 2* Performance

2.1 General

2.1.1 Unless the main steering gear comprises two or more identical power units, in accordance with 2.1.4, every ship is to be provided with a main steering gear and an auxiliary steering gear in accordance with the requirements of the Rules. The main steering gear and the auxiliary steering gear are to be so arranged that the failure of one of them will not render the other one inoperative.

2.1.2 The main steering gear and rudder stock is to be:

(a) Of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated in accordance with 5.2;

(b) The parts comprising the steering gear are to be so dimensioned that they can withstand all the maximum stresses to which they will be subjected in normal operating conditions. The steering gear is to be sufficiently strong to withstand abnormal forces (e.g. when the rudder is touching bottom or a bank), the maximum possible damage in such cases being limited to deformation or fracturing of the rudder or stock.

(c) The steering gear is to be so designed that a rudder angle of not less than 35° on either side can be obtained. On ships where, due to operation in restricted waters or the passage of locks, a higher degree of manoeuvrability is required, this angle is to be suitably increased;

(d) Where the steering gear is manually operated, one complete turn of the hand wheel is to correspond to at least 3° of rudder angle;

(e) Where the steering gear is power driven, it is to be capable of turning the rudder at an average rate of 4° per second through the entire rudder arc when the rudder is fully immersed and with the ship at maximum ahead service speed.

2.1.3 The auxiliary steering gear is to be:

(a) Of adequate strength and capable of steering the ship at a speed of not less than 13 km/h and of being brought speedily into action in an emergency;

(b) The steering gear is to be so designed that a rudder angle of not less than 35° on either side can be obtained. On ships where, due to operation in restricted waters or the passage of locks, a higher degree of manoeuvrability is required, this angle is to be suitably increased;

(c) The steering gear and its source of power is to be designed for an operation of not less than 30 minutes and to permit the ship to proceed to a mooring;

(d) Where the steering gear is manually operated, one complete turn of the hand wheel is to correspond to at least 3° of rudder angle;

(e) Where the steering gear is power driven, it is to be capable of turning the rudder at an average rate of 4° per second through the entire rudder arc when the rudder is fully immersed, and with the ship at a speed of not less than 13 km/h.

2.1.4 Where the main steering gear comprises two or more identical power units, an auxiliary steering gear need not be fitted, provided that:

(a) In a passenger ship, the main steering gear is capable of operating the rudder as required by 2.1.2(b) while any one of the power units is out of operation;

(b) In a cargo ship, the main steering gear is capable of operating the rudder as required by 2.1.2(b) while operating with all power units;

(c) The main steering gear is arranged so that after a single failure in its piping system or in one of the power units the defect can be isolated so that steering capability can be maintained or speedily regained.

2.1.5 Main and auxiliary steering gear power units are to be:

(a) Arranged to re-start immediately by manual initiation;

(b) Capable of being brought into operation from a position on the wheelhouse. In the event of a power failure to any one of the steering gear power units, an audible and visual alarm is to be given on the wheelhouse;

(c) Arranged so that transfer between units can be readily effected.

2.1.6 Steering gear, other than of the hydraulic type, will be accepted provided the standards are considered equivalent to the requirements of this Section.

2.1.7 Manually operated gears are only acceptable when the operation does not require an effort exceeding 160 N under normal conditions.

2.2 Rudder angle limiters

2.2.1 Power driven steering gears are to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronized with the gear itself and not with the steering gear control. Limit switches may be omitted for steering gear having rudder angles exceeding 45° each side.

■ *Section 3* Construction and design

3.1 General

3.1.1 The entire steering gear is to be designed, constructed and installed to allow for a permanent transverse list of up to 15° and for ambient temperatures commensurate with the area in which the ship is to operate.

3.1.2 Rudder actuators are to be designed in accordance with the relevant requirements of Chapter 9 for Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

3.1.3 Accumulators, if fitted, are to comply with the relevant requirements of Chapter 9.

3.1.4 The welding details and welding procedures are to be approved. All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be of full penetration type or of equivalent strength.

3.1.5 The construction is to be such as to minimize local concentrations of stress.

3.1.6 The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure taking into account any pressure which may exist in the low pressure side of the system.

3.1.7 For the rudder actuator, the permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \text{ or } \frac{\sigma_y}{B}$$

where

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0,2 per cent proof stress of the material, at ambient temperature

A and *B* are given by Table 15.3.1.

Table 15.3.1 Material factors of safety

	Wrought steel	Cast steel	Nodular cast iron
A	3,5	4	5
B	1,7	2	3

3.1.8 No other consumers may be connected to the hydraulic steering gear drive unit.

3.2 Components

3.2.1 Special consideration is to be given to the suitability of any essential component which is not duplicated. Any such essential component shall, where appropriate, utilize anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which shall be permanently lubricated or provided with lubrication fittings.

3.2.2 All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

3.2.3 Actuator oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal type or of an equivalent type.

3.2.4 Actuator oil seals between moving parts, forming part of the external pressure boundary, are to be such that the failure of one seal does not render the actuator inoperative.

3.2.5 Piping, joints, valves, flanges and other fittings are to comply within the requirements of Chapter 10 for Class I piping systems components. The design pressure is to be in accordance with 3.1.6.

3.2.6 Hydraulic power operated steering gears are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system.

3.3 Valve and relief valve arrangements

3.3.1 For vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

3.3.2 Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

3.3.3 Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The settings of the relief valves are not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

3.3.4 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by 3.3.3, are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure.

(b) The minimum discharge capacity of the relief valve(s) is not to be less than 110 per cent of the total capacity of the pumps which can deliver through it (them). Under such conditions the rise in pressure is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

3.4 Flexible hoses

3.4.1 Hose assemblies approved by Lloyd's Register may be installed between two points where flexibility is required. In general, the hose should be limited to the length necessary to provide for flexibility and for proper operation of machinery, *see* Ch 10,8 for the applicable requirements.

■ *Section 4*
Steering control and electric power systems

4.1 Fully powered steering gear

4.1.1 Fully powered steering gears may be of the direct electric or electric/hydraulic type; requirements for the electric and control engineering, *see also* Pt 6, Ch 1,3.7 and Ch 2,9.

4.1.2 Powered steering gears are to be fitted with means to limit the torque exerted by the drive.

4.1.3 In case of failure of the main drive and the secondary drive not engaging automatically, it is to be possible to engage the secondary drive by hand at the steering position within five seconds, with the rudder in any position.

4.1.4 At the steering station, automatic indication is to be provided as to which drive is in operation.

4.1.5 If the independent secondary drive is manual the power drive is not to actuate the hand wheel. A device is to be fitted to prevent inadvertent turning of the hand wheel when the manual drive is engaged automatically.

4.1.6 Where the main steering gear is power operated whilst the secondary steering is a manually operated hydraulic system, the piping of both systems is to be completely separate, and the main installation is to operate without using the steering wheel pump of the secondary installation.

4.1.7 Where both the main and secondary drive is power hydraulic, the respective pumps are to be driven independently.

4.1.8 Where the secondary pump is driven by an engine which does not operate continuously whilst the ship is in motion, means are to be provided to operate the steering gear instantly whilst the emergency engine is gaining the required speed.

4.1.9 The two installations are to have separate pipes, valves, controls, etc. Where the independent functioning of the two installations is ensured, they may have common components.

4.1.10 Where the steering gear is so arranged that more than one power system can be simultaneously operated, the risk of hydraulic locking caused by a single failure is to be considered.

4.2 Manual drive

4.2.1 Where the sole steering installation is a manually operated system, an independent secondary steering system is not required, provided that in the case of a hydraulic system the dimensioning, construction and layout of the piping precludes deterioration through mechanical action or fire, and the construction of the steering wheel pump ensures faultless operation.

4.2.2 A manually operated steering gear may be supplemented by a power assistance installation provided the steering assistance gear is capable of being engaged or disengaged at the steering station with the rudder in any position and the ‘on’ position is clearly indicated.

4.2.3 If a power assisted manual drive is fitted as a secondary means of steering, the power assistance installation is to be completely separate from the main steering system and is not to preclude compliance with 4.1.3 to 4.1.5.

4.3 Rudder position

4.3.1 If the position of the rudder(s) is not clearly discernable from the steering station, a reliable rudder angle indicator is to be provided at the steering station.

4.3.2 Any rudder angle indicator fitted, is to function for both the main and secondary steering gear.

■ *Section 5* Testing and trials

5.1 Testing

5.1.1 The requirements of the Rules relating to the testing of Class I pressure vessels, piping, and related fittings including hydraulic testing, apply.

5.1.2 After installation on board the vessel the steering gear is to be subjected to the required hydrostatic and running tests.

5.1.3 Each type of power unit pump is to be subjected to a type test. The type tests may be waived for a power unit which has been proven to be reliable in marine service.

5.2 Trials

5.2.1 The steering gear is to be tried out on the trial trip in order to demonstrate to the Surveyor's satisfaction that the requirements of the Rules have been met. The trial is to include the operation of the following:

(a) The steering gear, including demonstration of the performances required by 2.1.2(d) and (e) and 2.1.3(d) and (e):
- For the main steering gear trial, the propeller pitch of controllable pitch propellers is to be at the maximum design pitch approved for the maximum continuous ahead RPM;
- If the ship cannot be tested at the deepest draught, alternative trial conditions may be specially considered. In this case, for the main steering gear trial, the speed of the ship corresponding to the maximum continuous revolutions of the main engine should apply.

(b) The steering gear power units, including transfer between steering gear power units;
(c) The isolation of one power actuating system, checking the time for regaining steering capability;
(d) The operation of the auxiliary steering gear as required by 2.1.3(c);
(e) The steering gear controls, including transfer of control and local control;
(f) The alarms and indicators;
(g) Where the steering gear is designed to avoid hydraulic locking, this feature shall be demonstrated.

Test items (f) and (g) may be effected at the dockside.

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter applies to azimuth or rotatable thruster units for propulsion, which transmit a power greater than 220 kW used as the sole means of steering, and are in addition to the relevant requirements of Chapter 15.

1.1.2 Azimuth or rotatable thruster units for propulsion where the power exceeds 2000 kW are to comply with the relevant requirements of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as Rules for Ships).

1.1.3 A minimum of two azimuth thruster units are to be provided where these form the sole means of propulsion.

1.1.4 The failure of one azimuth thruster unit or its control system is not to render any other thrusters inoperative.

1.2 Plans

1.2.1 The following additional plans are to be submitted for consideration together with particulars of materials and the maximum shaft power and revolutions per minute:

- Sectional assembly including nozzle ring structure, nozzle support struts, etc.
- Shafts, gears and couplings.
- Steering mechanisms with details of ratings.
- Bearing specifications.
- Schematic piping systems of lubricating and hydraulic systems together with pipe material, relief valves and working pressures.

■ *Cross-references*

For strengthening for Navigation in Ice, *see* Chapter 7.
For general piping requirements, *see* Chapters 10, 11 and 12.
For steering gear, *see* Chapter 15.

■ *Section 2* Performance

2.1 General

2.1.1 The arrangement of thrusters is to be such that the ship can be satisfactorily manoeuvred.

2.1.2 In addition to the requirements of Chapter 15, the azimuthing mechanism is to be capable of a maximum rotational speed of not less than 1,5 rev/min.

■ *Section 3* Construction and design

3.1 Materials

3.1.1 Specification for materials of gears, shafts, couplings and propeller, giving chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.1.2 Specification for materials for the stock, struts, etc., are to be submitted for approval.

3.1.3 Where an ice class notation is included in the class of a ship, additional requirements are applicable as detailed in Chapter 7 and Pt 3, Ch 9,3.

3.2 Design

3.2.1 For steerable thrusters with or without nozzle, the stresses in the nozzle stock or steering pipe are to be determined as follows:

$$\sigma_B = \frac{M_B}{Z_B}$$

$$\tau_T = \frac{M_T}{Z_T}$$

$$\sigma_E = \sqrt{\sigma_B^2 + 3\,\tau_T^2}$$

where

σ_B = bending stress, in N/mm^2
M_B = bending moment at any section x-x, in Nmm and is to be determined as follows:
$M_B = 10^6\, T_M\, a$

where

T_M = maximum thrust of the thruster unit, in kN
a = dimension from centreline propeller to plane of consideration, in metres, as shown in Fig. 16.3.1
Z_B = section modulus against bending, in mm^3
τ_T = torsional stress, in N/mm^2
M_T = the maximum torque at the relief valve pressure which is generally equal to the design torque as specified by the steering gear manufacturer, in Nmm
Z_T = section modulus against torsion, in mm^3
σ_E = equivalent stress in N/mm^2.

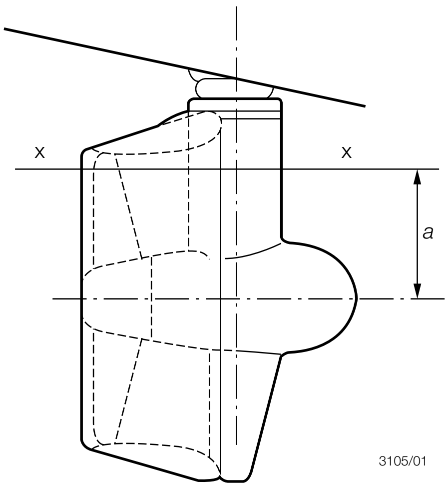

Fig. 16.3.1 Steerable thruster

3.2.2 **Permissible stresses**:

Torsional stress $\tau_T = \dfrac{68}{k_o}$ N/mm^2

Equivalent stress $\sigma_E = \dfrac{118}{k_o}$ N/mm^2

where

k_o is a material factor as in Table 16.3.1.

For all items calculated, a material factor, k_o, may be used if the material has a better quality than regular carbon steel.

Table 16.3.1 Material factor

σ_o	$k_o/k_b/k_s$
For $\sigma_o > 235$	$\left(\dfrac{235}{\sigma_o}\right)^{0,75}$
For $\sigma_o \le 235$	$\left(\dfrac{235}{\sigma_o}\right)$
Symbols	
σ_o = minimum yield stress in N/mm^2 k_o = higher steel correction factor k_b = coupling bolt material factor k_s = rudderstock or steering pipe flange material factor	
NOTES 1. σ_o is to be taken not greater than 70 % of the ultimate tensile strength or 450 N/mm^2, whichever is the lesser. 2. For bolts, σ_o may be taken not greater than 70 per cent% chever is the lesser.	

3.2.3 For coupling bolts, steering pipe/underwater gearbox the requirements of 3.2.4 and 3.2.5 apply.

3.2.4 **Tap bolts or bolts in clearance holes:**

The minimum diameter of tap bolts or of bolts in clearance holes at the joining faces of connecting flanges, pretensioned to 70 per cent of the bolt material yield strength value, is to be not less than:

$$\delta_b = 1,348 \sqrt{\left(\frac{10\,\pi\,M_T}{d_c}\right)\frac{1}{n\,\sigma_y}}$$

where

M_T = maximum turning moment, in Nmm, *see also* 3.2.1

n = number of bolts

σ_y = bolt material yield stress, in N/mm^2

d_c = pitch circle of the bolts, in mm.

3.2.5 Fitted bolts will be specially considered.

3.2.6 The minimum thickness, t_f, in mm of the coupling flange:

$$t_f = \delta_b \sqrt{\frac{k_b}{k_s}}$$

where

δ_b = diameter of the coupling bolts, in mm

k_b and k_s are as defined in Table 16.3.1.

The thickness of the coupling flange is in no case to be less than the actual diameter of the coupling bolts.

3.2.7 The fillet radius at the base of the connecting flange of the steering pipe is to be not less than 0,06 of the diameter of the steering pipe at the flange. A smaller fillet radius can be accepted based on a suitable calculation method in which the effects of stress concentration are to be taken into account.

3.2.8 The nozzle structure is to be in accordance with Pt 3, Ch 12,3.

3.2.9 As an alternative to this Chapter, azimuth thrusters in full compliance with Pt 5, Ch 20 of the Rules for Ships are also acceptable for Inland Waterways Rules applications.

3.3 Steering gear elements

3.3.1 These gears are to be considered for the following conditions:

- a design maximum dynamic duty steering torque;
- a static duty ($\le 10^3$ load cycles) steering torque, and the static duty steering torque should be not less than M_T.

Values for the above should be submitted together with the plans.

3.4 Components

3.4.1 The hydraulic power operating systems for each azimuth thruster are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system.

3.4.2 Where the lubricating oil for the azimuth thrusters is circulated under pressure, provision is to be made for the efficient filtration of the oil.

3.4.3 For flexible hoses, reference is made to Ch 10,8.

3.5 Locking of thruster unit

3.5.1 Azimuth propulsion systems are to be capable of being locked in a fixed position, *see also* Ch 15,1.6.3.

3.6 Prime movers

3.6.1 Diesel engines intended for driving thrusters are to comply with the applicable requirements of Chapter 2.

3.7 Gears

3.7.1 The gears are to be in compliance with the applicable requirements of Chapter 3 with an application factor K_A in Table 3.3.1 and a factor of safety for contact stress and bending as intended for multiple screw applications, *see* Table 3.3.4. As an alternative to Chapter 3, gear elements may be designed in accordance with ISO 6336, Parts 1, 2, 3 and 5.

3.8 Shafts

3.8.1 The diameter of screw shaft is to be not less than required by Ch 4,3.

3.8.2 Torsional vibration characteristics of the shaft system are to be in compliance with Chapter 6.

3.8.3 Calculations of the lateral vibration characteristics of shafting systems incorporating cardan shafts are to be submitted in accordance with Chapter 6.

3.9 Propellers

3.9.1 Propellers are to be in compliance with the requirements of Chapter 5.

■ *Section 4* Control engineering arrangements

4.1 General

4.1.1 Except where indicated in this Section, the control engineering systems are to be in accordance with Pt 6, Ch 1.

4.1.2 Steering control is to be provided for the azimuth thrusters from the wheelhouse.

4.1.3 An indication of the angular position of the thrusters and the magnitude of the thrust are to be provided at the wheelhouse from which it is possible to control the direction of thrust.

4.1.4 Means are to be provided to stop each thrust unit locally and at the wheelhouse.

4.2 Monitoring and alarms

4.2.1 Alarms and monitoring requirements are indicated in 4.2.2 and Table 16.4.1.

Table 16.4.1 Alarms for control systems

Item	Alarm	Note
Thruster azimuth	—	Indicator, *see* 4.1.3
Steering motor	Power failure, single phase	Also running indication at wheelhouse
Propulsion motor	Power failure	Also running indication at wheelhouse
Control system power	Failure	
Hydraulic oil supply tank level	Low	
Hydraulic oil system pressure	Low	
Hydraulic oil system temperature	High	Where oil cooler is fitted
Hydraulic oil filters differential pressure	High	Where oil filters are fitted
Lubricating oil supply	Low	If separate forced lubrication

4.2.2 The alarms described in Table 16.4.1 are to be indicated individually on the wheelhouse and in accordance with the alarm system specified by Pt 6, Ch 1,2.3.

■ *Section 5* Electrical equipment

5.1 General

5.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of 5.2 to 5.4.

5.1.2 Where the thruster units are electrically driven, the relevant requirements, including surveys, of Pt 6, Ch 2 are to be complied with.

5.2 Generating arrangements

5.2.1 Where a central power generation system is employed, the requirements of Pt 6, Ch 2,2.3 are to be complied with.

5.2.2 The generating and distribution system is to be so arranged that after any single failure, steering capability can be maintained or regained immediately, and the effectiveness of the steering after such a fault will not be reduced by more than 50 per cent. This may be achieved by the parallel operation of two or more generating sets, or alternatively when the electrical requirements may be met by one generating set in operation, on loss of power, the automatic starting and connection to the switchboard of a standby set, provided that this set can restart and run a thruster with its auxiliaries.

5.2.3 The failure of one thruster unit or its control system is not to render any other thruster inoperative.

5.2.4 A single failure of generator/switchboard should not lead to failure of any other generator/switchboard.

5.3 Distribution arrangements

5.3.1 Thruster auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, convertors, protective devices or control circuits.

5.4 Auxiliary supplies

5.4.1 Where the auxiliary services and thruster units are supplied from a common source, the following requirements are to be complied with:
(a) The voltage regulation and current sharing requirements defined in Pt 6, Ch 2,4.5 are to be maintained over the full range of power factors that may occur in service.
(b) Auxiliary equipment and services are to operate with any waveform distortion introduced by convertors without deleterious effect (this may be achieved by the provision of suitably filtered/converted supplies).
(c) The thrusters should not influence the other essentials.

■ *Section 6* Testing and trials

6.1 General

6.1.1 The requirements detailed in Chapters 1, 3 and 15 are to be complied with and, in addition, the performance specified in 2.1.2 is to be demonstrated to the Surveyor's satisfaction.

6.1.2 The actual values of steering torque should be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

■ *Section 1*
General requirements

1.1 Application

1.1.1 This Chapter applies to bow thruster units intended for manoeuvring having a power of 110 kW and over, fitted on ships with a length exceeding 110 m. *See also* Ch 1,5.

1.1.2 Thrusters of less than 110 kW are to be built in accordance with good engineering practice and tested as required in 6.1.

1.2 Plans

1.2.1 The following plans are to be submitted for consideration, together with particulars of materials and the maximum shaft power and revolutions per minute:

- Sectional assembly.
- Shafts, sealing devices, gears and couplings.
- Steering mechanisms with details of ratings.
- Bearing specifications.
- Schematic piping systems.
- Propeller/impeller where the diameter exceeds 1 m.
- For CPP installations, pitch control device.
- Structure of the tunnel showing details and thicknesses.

■ *Cross-references*

For strengthening for Navigation in Ice, *see* Chapter 7.
For general piping requirements, *see* Chapters 10, 11 and 12.
For steering gear, *see* Chapter 15.
For azimuth or rotatable thruster units, *see* Chapter 16.

■ *Section 2*
Performance

2.1 General

2.1.1 The arrangement of the bow thruster is to be such that the ship can maintain a speed of not less than 7 km/h in the unloaded condition and can be satisfactorily manoeuvred as per Ch 1,5.

■ *Section 3*
Construction and design

3.1 Materials

3.1.1 Specification for materials of gears, shafts, couplings and propeller, giving chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.1.2 Specification for materials for the stock, etc., are to be submitted for approval.

3.1.3 Where an ice class notation is included in the class of a ship, additional requirements are applicable as detailed in Chapter 7 and Pt 3, Ch 9,3.

3.2 Design

3.2.1 For steerable bow thrusters, the maximum transmitted torque, M_T, is to be the greater of:

- Manufacturers rating.
- Calculated maximum torque generated by steering motor.

3.2.2 The tunnel structure and/or container in which the thrust unit is fitted, is to be in compliance with Pt 3, Ch 12,4.

3.3 Steering gear elements

3.3.1 These gears are to be considered for the following conditions:

- A design maximum dynamic duty steering torque;
- A static duty ($\leq 10^3$ load cycles) steering torque to be not less than M_T.

Values for the above should be submitted together with the plans.

3.3.2 The rudderstock diameter is to be not less than:

$$d_r = 3{,}38 \times \sqrt[3]{\frac{M_T}{\sigma_u}} \text{ mm}$$

where
M_T = maximum transmitted torque, in Nmm
σ_u = ultimate tensile strength of the rudderstock material, in N/mm^2.

3.4 Components

3.4.1 The hydraulic power operating systems for steering the bow thruster are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system.

3.4.2 Relief valves are to be fitted to any part of the hydraulic system which can be isolated. The settings of the relief valves are not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

3.4.3 For flexible hoses, reference is made to Ch 10,8.

3.5 Prime movers

3.5.1 Diesel engines intended for driving thrusters are to comply with the applicable requirements of Chapter 2.

3.6 Gears

3.6.1 The gears are to be in compliance with the applicable requirements of Chapter 3 with application factors intended for auxiliary gears.

3.7 Shafts

3.7.1 The diameter of protected screw shafts is to be not less than that required for a screw shaft as per Ch 4,3.4.2, in which 94 as per the formula, may be substituted by 85. For unprotected shafts, Ch 4,3.4.6 will be applicable.

3.7.2 Torsional vibration characteristics of the shaft system are to be in compliance with Chapter 6 for bow thrust units exceeding 500 kW power output.

3.7.3 Calculations of the lateral vibration characteristics of shafting systems incorporating cardan shafts are to be submitted in accordance with Chapter 6.

3.8 Propellers

3.8.1 Propellers intended for manoeuvring as in Ch 1,5 are to be in compliance with the requirements of Chapter 5.

■ *Section 4* Control engineering arrangements

4.1 General

4.1.1 Except where indicated in this Section, the control engineering systems are to be in accordance with Pt 6, Ch 1.

4.1.2 Steering control is to be provided for the bow thruster unit from the wheelhouse.

4.1.3 An indication of the angular position of the thruster(s) and the magnitude of the thrust are to be provided at the wheelhouse from which it is possible to control the direction of thrust.

4.1.4 Means are to be provided at the wheelhouse to stop the thrust unit.

4.2 Monitoring and alarms

4.2.1 Alarms and monitoring requirements are indicated in 4.2.2 and Table 17.4.1.

Table 17.4.1 Alarms for control systems

Item	Alarm	Note
Thruster steerable	—	Indicator, *see* 4.1.3
Steering motor	Power failure, single phase	Also running indication at wheelhouse
Propulsion motor	Power failure	Also running indication at wheelhouse
Control system power	Failure	
Hydraulic oil supply tank level	Low	
Hydraulic oil system pressure	Low	
Hydraulic oil system temperature	High	Where oil cooler is fitted
Hydraulic oil filters differential pressure	High	Where oil filters are fitted
Lubricating oil supply	Low	If separate forced lubrication

4.2.2 The alarms described in Table 17.4.1 are to be indicated individually on the wheelhouse and in accordance with the alarm system specified by Pt 6, Ch 1,2.3.

■ *Section 5* Electrical equipment

5.1 General

5.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of 5.2 to 5.4.

5.1.2 Where the thruster units are electrically driven, the relevant requirements, including surveys, of Pt 6, Ch 2 are to be complied with.

5.2 Generating arrangements

5.2.1 Where a central power generation system is employed, the requirements of Pt 6, Ch 2,2.3 are to be complied with. The power generation system for the bow thruster is to be located in the fore ship.

5.2.2 Remote start stop including power generating is to be provided.

5.2.3 The stop of the bow thruster unit is to be independent of direction speed control.

5.3 Distribution arrangements

5.3.1 Thruster auxiliaries and controls are to be served by individual circuits which are to be located in the fore ship.

5.4 Auxiliary supplies

5.4.1 Where the auxiliary services and thruster units are supplied from a common source, the following requirements are to be complied with:

(a) The voltage regulation and current sharing requirements defined in Pt 6, Ch 2,4.5 are to be maintained over the full range of power factors that may occur in service.

(b) Auxiliary equipment and services are to operate with any waveform distortion introduced by convertors without deleterious effect (this may be achieved by the provision of suitably filtered/converted supplies).

(c) The bow thruster should not influence the other essentials.

■ *Section 6*
Testing and trials

6.1 General

6.1.1 The requirements detailed in Chapters 1, 3, 10 and 15 are to be complied with and, in addition, the performance specified in 2.1.1 is to be demonstrated to the Surveyor's satisfaction.

6.1.2 The actual values of steering torque should be verified during trials to confirm that the design maximum torque has not been exceeded.

6.1.3 The manufacturer's test certificate for materials for the rotating equipment and steering gear will be accepted in lieu of Lloyd's Register's (hereinafter referred to as LR) materials certificate provided they are to be produced at a works approved by LR and are tested in accordance with the appropriate requirements of the *Rules for the Manufacture, Testing and Certification of Materials*.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to the design and construction of hydraulic systems for raising and lowering of wheelhouses on all types of ships except where otherwise stated.

1.1.2 Special attention is drawn to National and International technical and operational requirements of countries where the ship is registered or operating and which are outside classification as defined in these Rules.

1.1.3 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules.

1.1.4 For a general description and definitions of elevating wheelhouse systems, *see* Pt 3, Ch 13,1.

1.2 Plans and particulars

1.2.1 The following plans and particulars are to be submitted for approval:

- Arrangement plan of hydraulic cylinder.
- Detail plans of hydraulic cylinder.
- Plans showing connections of cylinder(s) to wheelhouse and cylinder(s) to ship.
- Diagram of hydraulic system.
- Working and relief pressure of hydraulic system.
- For synchronised telescopic cylinders, the working and relief pressure for each compartment.

1.3 Materials

1.3.1 All the components raising the wheelhouse are to be of sound reliable construction to the Surveyor's satisfaction.

1.3.2 All components transmitting mechanical forces to the wheelhouse are to be tested according to the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.3.3 The cylinders, hydraulic power piping, valves, flanges and fittings and all components transmitting mechanical forces to the wheelhouse are to be of steel or other approved ductile material, duly tested in accordance with the requirements of the Rules for Materials. In general, such material is to have an elongation of not less than 12 per cent nor a tensile strength in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for valve bodies and redundant parts with low stress levels.

1.3.4 Materials for cylinders having a design temperature less than 0°C are to be in compliance with the Rules for Materials and Charpy-V testing is to be carried out as per the Rules.

1.3.5 Where appropriate, consideration will be given to the acceptance of non-ferrous material.

■ *Section 2* Pumping and piping

2.1 Hydraulic systems for elevating wheelhouses

2.1.1 For general requirements on hydraulic systems, *see* Pt 5, Ch 12,9.

2.1.2 Arrangements are to be provided to avoid an uncontrolled lowering of the wheelhouse in case of hose rupture.

2.1.3 An emergency lowering arrangement operable from the wheelhouse is to be provided.

2.1.4 Arrangements are to be provided to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system.

2.1.5 Stopping of wheelhouse lowering is to be such as to avoid an undue rise in pressure in the hydraulic system above the design pressure. *See also* Pt 6, Ch 1,3.9.2.

2.1.6 For hydraulic test on pipes and fittings, *see* Ch 10,9.

2.2 Hydraulic pumps

2.2.1 A standby hydraulic pump is to be provided.

2.2.2 The standby pump is to be connected ready for immediate use.

2.2.3 For over-pressure protection of the pumps, *see* Ch 12,9.2.3.

2.2.4 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

2.3 Flexible hoses for elevating wheelhouse

2.3.1 Hose assemblies approved by Lloyd's Register may be installed between two points where flexibility is required but are not to be subjected to torsional deflection (twisting) under normal operating conditions. In general, the hose should be limited to the length necessary to provide for flexibility and for proper operation of machinery.

2.3.2 Service life time of flexible hoses is not to exceed Manufacturer's recommendations.

2.3.3 In addition to the above the requirements of Ch 10,8 are to be complied with as far as they are applicable.

■ *Section 3* Hydraulic cylinder

3.1 Hydraulic cylinder

3.1.1 Hydraulic cylinders are to be designed in accordance with the relevant requirements of Chapter 9 for Class 1 pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

3.1.2 Accumulators, if fitted, are to comply with the relevant requirements of Chapter 9.

3.1.3 The welding details and welding procedures are to be approved. All welded joints within the pressure boundary or connecting parts transmitting mechanical loads are to be full penetration type or of equivalent strength.

3.1.4 The construction is to be such as to minimize local concentrations of stress.

3.1.5 The design pressure for calculations to determine the scantlings of piping and other components subjected to internal hydraulic pressure shall be at least 1,2 times the maximum working pressure to be expected under normal operating conditions.

3.1.6 Actuator oil seals between moving parts, forming part of the external pressure boundary, are to be provided with a single pressure seal plus a wiper seal. Alternative arrangements providing equivalent protection against leakage may be accepted.

3.1.7 The design of synchronised telescopic cylinders is to be such that the working pressure in each compartment shall not exceed the design pressure of that compartment under all conditions of service, otherwise each compartment is to be provided with a safety relief valve discharging to atmospheric pressure.

3.2 Allowable stresses hydraulic cylinder

3.2.1 The permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \quad \text{or} \quad \frac{\sigma_y}{B}$$

where

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0,2 per cent proof stress of the material, at ambient temperature

A and *B* are given by the following Table:

	Wrought steel	*Cast steel*	*Nodular cast iron*
A	3,5	4	5
B	1,7	2	3

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RULES AND REGULATIONS FOR THE CLASSIFICATION OF INLAND WATERWAYS SHIPS

CONTROL, ELECTRICAL AND FIRE

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PART 6

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■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter applies to all ships and is in addition to other relevant Sections of the Rules.

1.1.2 Attention should also be given to any relevant requirements of National, International or Local Authorities which would apply to the ships in service.

1.1.3 This Chapter states requirements for systems of automatic or remote control which may be used for controlling the machinery contained in 1.2.2. The design and installation of other control equipment is to be such that there is no risk of danger due to failure.

1.1.4 The details of control systems will vary with the type of machinery being controlled and special consideration will be given to each case.

1.2 Plans

1.2.1 Where control systems are applied to essential machinery or equipment as listed in 1.2.2, plans are to be submitted in triplicate. They are to include or to be accompanied by:

Details of operating medium, i.e. pneumatic, hydraulic or electric, including standby sources of power.
Description and/or block diagram showing method of operation.
Line diagrams of control circuits.
Lists of points monitored.
List of alarm points.
List of control points.
Test facilities provided.
Test schedules.
Location drawings of fire detectors.
List of safety functions and details off any overrides, including consequences of use, *see* 2.4.9.

1.2.2 **Control, alarm and safety systems.** Plans are required for the following:

Ballast systems.
Bilge systems.
Cargo pumping systems for tankers.
Controllable pitch propellers.
Electrical generating plant.
Fire detection systems.
Main propelling machinery including essential auxiliaries.
Steam raising plant.
Transverse thrust units.
Steering gear plant.
Inert gas generators.
Thermal fluid heaters.

1.2.3 **Alarm systems.** Details of the overall alarm system linking engine room, wheelhouse and, where applicable, accommodation spaces are to be submitted.

1.2.4 **Programmable electronic systems.** In addition to the documentation required by 1.2.2, the following is to be submitted:

System requirements specification.
Details of the hardware configuration in the form of a system block diagram, including input/output schedules.
Hardware certification details, *see* 2.9.4.
Software quality plans, including applicable procedures.
Factory acceptance and sea trial test schedules for hardware and software.

1.2.5 **Control station**. Location and details of control stations are to be submitted, e.g. control panels.

1.2.6 **Standard system**. Where it is intended to employ a system which has been previously approved, plans may not be required to be submitted. The building port, where applicable, and date of the previous approval is to be advised.

1.3 Alarm and control equipment

1.3.1 Major units of equipment associated with control, alarm and safety systems as defined in 1.2 are to be surveyed at the manufacturers' works and the inspection and testing is to be to the Surveyor's satisfaction.

1.3.2 Equipment used in control, alarm and safety systems should, whenever practicable, be selected from the *List of Type Approved Control and Electrical Equipment* published by LR. A copy of LR's *Test Requirements for the Type Approval of Control and Electrical Equipment* will be furnished on application.

1.3.3 Assessment of performance parameters, such as accuracy, repeatability, etc., are to be in accordance with an acceptable National or International Standard.

1.4 Alterations and additions

1.4.1 When an alteration or addition to the approved system(s) is proposed, plans are to be submitted for approval. The alterations or additions are to be carried out under survey, and the inspection, testing and installation are to be to the Surveyor's satisfaction.

1.4.2 Details of proposed software modifications are to be submitted for consideration. Where the modification may affect compliance with these Rules, proposals for verification and validation are also to be submitted.

1.4.3 Software versions are to be uniquely identified by number, date or other appropriate means. Modifications are not to be made without also changing the version identifier. A record of changes to the system since the original issue (and their identification) is to be maintained and made available to the LR Surveyor on request.

■ *Section 2* Essential features for control, alarm and safety systems

2.1 General

2.1.1 Where it is proposed to install control and alarm systems to the equipment defined in 1.2.2, the applicable features contained in 2.2 to 2.6 are to be incorporated in the system design.

2.2 Control station(s) for machinery

2.2.1 A system of alarm displays and controls are to be provided which readily ensure identification of faults in the machinery and satisfactory supervision of related equipment.

2.3 Alarm systems

2.3.1 Where an alarm system which will provide warning of faults in the machinery and the safety and control systems is installed, the requirements of 2.3.2 to 2.3.13 are to be satisfied.

2.3.2 Machinery, safety and control system faults are to be indicated at the relevant control station to advise duty personnel of a fault condition.

2.3.3 Individual alarm channels may be displayed as group alarms at the main control station (if fitted) or alternatively at subsidiary control stations.

2.3.4 All alarms are to be both audible and visual. If arrangements are made to silence audible alarms they are not to extinguish visual alarms. Alarm indicators are to be red and are to flash when unacknowledged.

2.3.5 If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, audible and visual alarms are again to operate. Unacknowledged alarms on monitors are to be distinguished by either flashing text or a flashing marker adjacent to the text. A change of colour will not in itself be sufficient to distinguish between acknowledged and unacknowledged alarms.

2.3.6 For the detection of transient faults which are subsequently self-correcting, alarms are required to lock in until accepted.

2.3.7 Failure of the power supply to the alarm system is to be indicated.

2.3.8 The alarm system should be designed with self-monitoring properties. As far as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

2.3.9 The alarm system is to be designed as far as practical to function independently of control systems such that a failure or malfunction on these systems will not prevent the alarm from operating.

2.3.10 Disconnection or manual overriding of any part of the alarm system should be clearly indicated.

2.3.11 The alarm system is to be capable of being tested.

2.3.12 The alarm system should be designed with self-monitoring properties. Insofar as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

2.3.13 In the wheelhouse, all illumination and lighting of instruments, keyboards and controls are to be adjustable down to zero, except the lighting of alarm indicators and the controls of dimmers which are to remain readable.

2.4 Safety systems – General requirements

2.4.1 Where safety systems are provided, the requirements of 2.4.2 to 2.4.13 are to be satisfied.

2.4.2 Safety systems are to operate automatically in case of serious faults endangering the machinery, so that:

(a) normal operating conditions are restored, e.g. by the starting of standby machinery, or
(b) the operation of the machinery is temporarily adjusted to the prevailing conditions, e.g. by reducing the output of the machinery, or
(c) the machinery is protected from critical conditions by shutting off the fuel or power supplies thereby stopping the machinery.

2.4.3 The safety system required by 2.4.2(c) is to be designed as far as practicable to operate independently of the control and alarm systems, such that a failure or malfunction in the control and alarm systems will not prevent the safety system from operating.

2.4.4 For safety systems required by 2.4.2(a) and (b) complete independence from other control systems is not necessary.

2.4.5 Safety systems for different items of the machinery plant are to be arranged so that failure of the safety system of one part of the plant will not interfere with the operation of the safety system in another part of the plant.

2.4.6 The safety system is to be designed to 'fail-safe'. The characteristics of the 'fail-safe' operation are to be evaluated on the basis not only of the safety system and its associated machinery, but also the complete installation. Failure of a safety system is to initiate an audible and visual alarm.

2.4.7 When a safety system is activated, an audible and visual alarm is to be provided to indicate the cause of the safety action.

2.4.8 The safety system is to be manually reset before the relevant machinery can be restarted.

2.4.9 Where arrangements are provided for overriding a safety system, they are to be such that inadvertent operation is prevented. Visual indication is to be given at the relevant control station(s) when a safety override is operated. The consequences of overriding a safety system are to be established and documented.

2.4.10 The safety system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply.

2.4.11 Failure of any power supply to a safety system is to operate an audible and visual alarm.

2.4.12 When safety systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.4.13 As far as practicable, the safety system required by 2.4.2(b) is to be arranged to effect a rapid reduction in speed or power.

2.5 Control systems

2.5.1 Control systems for machinery operations are to be stable throughout their operating range.

2.5.2 Failure of the power supply to a control system for propulsion machinery and associated systems is to operate an audible and visual alarm. *See* 3.5.1, 3.6.4 or 3.7.5, as applicable.

2.5.3 When remote or automatic controls are provided, sufficient instrumentation is to be fitted at the relevant control stations to ensure effective control and indicate that the system is functioning correctly.

2.5.4 Where valves are operated by remote or automatic control, the system of control should include the following safety features:

(a) Failure of actuator power should not permit a closed valve to open inadvertently.
(b) Positive indication is to be provided at the remote control station for the service to show the actual valve position or alternatively that the valve is fully open or closed. Valve position indicating systems are to be of an approved type.
(c) Equipment located in places which may be flooded should be capable of operating when submerged.
(d) A secondary means of operating the valves, which may be local manual control, is to be provided.

2.5.5 Control systems should be designed to 'fail-safe'. The characteristics of the 'fail-safe' operation are to be evaluated on the basis not only of the control system and its associated machinery, but also the complete installation.

2.6 Fire detection alarm systems

2.6.1 Where an automatic fire detection system is to be fitted in a machinery space, the requirements of 2.6.2 to 2.6.15 are to be satisfied.

2.6.2 A fire detector indicator panel is to be located in such a position that a fire in the machinery spaces will not render it inoperable.

2.6.3 The audible fire-alarm is to have a characteristic tone which distinguishes it from any other alarm system. The audible fire-alarm is to be audible on all parts of the bridge and in the accommodation areas.

2.6.4 The alarm system should, so far as practicable, be designed with self-monitoring properties.

2.6.5 Failure of any power supply to the alarm system is to be indicated.

2.6.6 Detector heads of an approved type are to be located in the machinery spaces so that all potential fire outbreak points are guarded.

2.6.7 The fire detection system is to be capable of being tested.

2.6.8 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective.

2.6.9 Fire detecting indicating panels are to denote, as a minimum, the section in which a detector or manually operated call point has operated. A section of detectors is not to cover more than 1 deck except a section which covers an enclosed stairway. No section of detectors is in general to include more than 50 detectors.

2.6.10 A section of fire detectors which covers loops of accommodations and control stations is not to include high fire risk spaces.

2.6.11 At least one indicating panel is to be so located that it is easily accessible to responsible members of the crew at all times. An indicating panel is to be located on the navigating bridge.

2.6.12 Clear information is to be displayed on or adjacent to each indicating unit about the spaces covered and the location of the section.

2.6.13 A combination of detectors is to be provided in order that the system will react to all possible fire characteristics.

2.6.14 A drawing showing the location of the fire detector heads and the fire indicator panel, is to be submitted.

2.6.15 Fire detection control units, indicating panels, detector heads and manual call points are to be Type Approved in accordance with Test Specification Number 1 given in LR's Type Approval System.

2.7 Programmable electronic systems – General requirements

2.7.1 The requirements of 2.7.2 to 2.7.21 are to be complied with where control, alarm or safety systems incorporate programmable electronic equipment. Systems for essential services and safety critical application and systems incorporating shared data communication links are to comply with the additional requirements of 2.8 and 2.9 as applicable.

2.7.2 Where programmable electronic systems share resources, any components that can affect the ability to effectively provide required control, alarm or safety functions are to fulfil the requirements of 2.7 to 2.9 related to providing those required functions.

2.7.3 Programmable electronic equipment is to revert to a defined safe state on initial start-up or re-start in the event of failure.

2.7.4 In the event of failure of any programmable electronic equipment, the system, and any other system to which it is connected, is to fail to a defined safe state or maintain safe operation, as applicable.

2.7.5 Programmable electronic equipment is to be certified by a recognized authority as suitable for the environmental conditions in which it is intended to operate.

2.7.6 Emergency stops are to be hard-wired and independent of any programmable electronic equipment.

2.7.7 Programmable electronic equipment is to be provided with self-monitoring capabilities such that hardware and functional failures will initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 4.2. Hardware failures are to be indicated at least at module level and the self-monitoring capabilities are to ensure that diagnostic information is readily available.

2.7.8 System configuration, programs and data are to be protected against loss or corruption in the event of failure of any power supply.

2.7.9 Access to system configuration, programs and data is to be restricted by physical and/or logical means providing effective security against unauthorized alteration.

2.7.10 Where date and time information is required by the equipment, this is to be provided by means of a battery backed clock with restricted access for alteration. Date and time information is to be fully represented and utilized.

2.7.11 Displays and controls are to be protected against liquid ingress due to spillage.

2.7.12 User interfaces are to be designed in accordance with appropriate ergonomic principles to meet user needs and enable timely access to desired information or control of functions. A system overview is to be readily available.

2.7.13 The keyboard is to be divided logically into functional areas. Alphanumeric, paging and specific system keys are to be grouped separately.

2.7.14 Where a function may be accessed from more than one interface, the arrangement of displays and controls is to be consistent.

2.7.15 The size, colour and density of information displayed to the operator are to be such that information may be easily read from the normal operator position under all operational lighting conditions.

2.7.16 Display units are to comply with the requirements of International Electrotechnical Commission Standard IEC 60950:1991, *Safety of information technology equipment, including electrical business equipment*, in respect of emission of ionising radiation.

2.7.17 Symbols used in mimic diagrams are to be visually representative and are to be consistent throughout the systems' displays.

2.7.18 Mimic diagrams are to clearly identify unreliable data.

2.7.19 Multi-function displays and controls are to be duplicated and interchangeable where used for the control or monitoring of more than one system is required at the same time. At least one unit at the main control station is to be supplied from an independent uninterruptible power supply (UPS).

2.7.20 The number of multi-function display and control units provided at the main control station and their power supply arrangements are to be sufficient to ensure continuing safe operation in the event of failure of any unit or any power supply.

2.7.21 Software lifecycle activities, e.g. design, development, supply and maintenance, are to be carried out in accordance with an acceptable quality management system. Software quality plans are to be submitted. These are to demonstrate that the provisions of ISO/IEC 90003:2004, *Software engineering – Guidelines for the application of ISO 9001:2000 to computer software*, or equivalent, are incorporated. The plans are to define responsibilities for the lifecycle activities, including verification, validation, module testing and integration with other components or systems.

2.8 Data communication links

2.8.1 Where control, alarm or safety systems use shared data communication links to transfer data, the requirements of 2.8.2 to 2.8.10 are to be complied with. The requirements apply to local area networks, field buses and other types of data communication link which make use of a shared medium to transfer control, alarm or safety related data between distributed programmable electronic equipment or systems.

2.8.2 Data communication is to be automatically restored within 45 seconds in the event of a single component failure. Upon restoration, priority is to be given to updating safety critical data and control, alarm and safety related data for essential services. Components comprise all items required to facilitate data communication, including cables, switches, repeaters, software components and power supplies.

2.8.3 Loss of a data communication link is not to result in the loss of ability to operate any essential service by alternative means.

2.8.4 The properties of the data communication link (e.g. bandwidth, access control method, etc.) are to ensure that all connected systems will operate in a safe, stable and repeatable manner under all operating conditions. The latency of control, alarm and safety related data is not to exceed two seconds.

2.8.5 Protocols are to ensure the integrity of control, alarm and safety related data, and provide timely recovery of corrupted or invalid data.

2.8.6 Means are to be provided to monitor performance and identify hardware and functional failures. An audible and visual alarm is to operate in accordance with the requirements of 2.3 and, where applicable, 4.2 in the event of a failure of an active or standby component.

2.8.7 Means are to be provided to prevent unintended connection or disconnection of any equipment where this may affect the performance of any other systems in operation.

2.8.8 Data cables are to comply with the applicable requirements of Ch 2,7. Other media will be subject to special consideration.

2.8.9 The installation is to provide adequate protection against mechanical damage and electromagnetic interference.

2.8.10 Components are to be located with appropriate segregation such that the risk of mechanical damage or electromagnetic interference resulting in the loss of both active and standby components is minimized. Duplicated data communication links are to be routed to give as much physical separation as is practical.

2.9 Programmable electronic systems – Additional requirements for essential services and safety critical systems

2.9.1 The requirements of 2.9.2 to 2.9.9 are to be complied with where control, alarm or safety systems for essential services or safety critical systems, incorporate programmable electronic equipment:

(a) Safety critical systems are those which provide functions intended to protect persons from physical hazards (e.g. fire, explosion, etc.), or to prevent mechanical damage which may result in the loss of an essential service (e.g. main engine low lubricating oil pressure shutdown).

(b) Applications that are not essential services may also be considered to be safety critical (e.g. domestic boiler low water level shutdown).

2.9.2 Alternative means of safe and effective operation are to be provided for essential services and, wherever practicable, these are to be provided by a fully independent hard-wired backup system. Where these alternative means are not independent of any programmable electronic equipment, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*.

2.9.3 Items of programmable electronic equipment used to implement control, alarm and safety functions are to satisfy the requirements of LR's *Type Approval System Test Specification Number 1 (2002)*, adjusted where applicable for operation solely in Seasonal Zones, *see also* Ch 2,1.5.1.

2.9.4 The system is to be configured such that control, alarm and safety function groups are independent. A failure of the system is not to result in the loss of more than one of these function groups. Proposals for alternative arrangements providing an equivalent level of safety will be subject to special consideration.

2.9.5 For essential services, the system is to be arranged to operate automatically from an alternative power supply in the event of a failure of the normal supply.

2.9.6 Failure of any power supply is to initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 4.2.

2.9.7 Where it is intended that the programmable electronic system implements emergency stop or safety critical functions, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*. Alternative proposals providing an equivalent level of system integrity will be subject to special consideration, e.g. fully independent hard-wired backup system, redundancy with design diversity, etc.

2.9.8 Control, alarm and safety related information is to be displayed in a clear, unambiguous and timely manner, and, where applicable, is to be given visual prominence over other information on the display.

2.9.9 Means of access to safety critical functions are to be dedicated to the intended function and readily distinguishable.

Section 3
Control and supervision of machinery

3.1 General

3.1.1 When machinery, as defined in 1.2.2, is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators then it is to be provided with the arrangements specified in 3.2 to 3.9. Alternative arrangements which provide equivalent safeguards will be considered.

3.1.2 Means are to be provided to prevent leaks from high pressure oil fuel injection piping for main and auxiliary engines dripping or spraying onto hot surfaces or into machinery air inlets. Such leakage is to be collected and, where practicable, led to a collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place. These requirements may also be applicable to high pressure hydraulic oil piping depending upon the location.

3.2 Oil engines for propulsion purposes

3.2.1 The following systems are to be provided with alarms:

System:	*Alarm:*
Lubricating oil pressure for the engine including gearing	Low
Lubricating oil pressure for the engine including gearing	Failure, *see* 3.2.2
Cooling system(s) temperature	High
Cooling system(s) temperature	Excessively high, *see* 3.2.3
Overspeed, for >37 kW	High, *see also* Pt 5, Ch 2,4

3.2.2 In the case of the lubricating oil system, in addition to the alarm indication as required by 3.2.1, at complete loss of lubricating oil the engine is to be stopped automatically or alternatively a second and separate alarm is to be provided giving audible and visual warning in the wheelhouse and in the engine room. The circuit and sensor employed for the automatic stop or alarm are to be additional to the alarm circuit and sensor required by 3.2.1.

3.2.3 In the case of cooling system(s), in addition to the alarm indication as required by 3.2.1, a shutdown system for excessively high temperature may be fitted which is to be independent of the alarm system.

3.2.4 Prolonged running in a restricted speed range is to be prevented automatically; alternatively, indication of restricted speed ranges is to be provided at each control station.

3.3 Boilers and thermal fluid heaters

3.3.1 A system of water level detection is to be fitted which will operate alarms and shut off automatically the oil supply to the burners when the water level falls to a predetermined low level.

3.3.2 The oil fuel is to be shut off automatically from the burners, and alarms are to operate on flame failure and failure of combustion air supply detected by either low pressure at the fan outlet or stopping of the fan motor.

3.3.3 Combustion spaces are to be purged automatically before re-ignition takes place in the event of a flame out on all burners.

3.3.4 For cargo heating systems, circulation pumps are to stop automatically in the event of low level and in the event of low pressure of thermal fluid circulation.

3.4 Auxiliary engines

3.4.1 The following systems for auxiliary engines of more than 37 kW (50 shp) are to be provided with alarms:

System:	*Alarm:*
Lubricating oil pressure	Low*
Cooling system temperature	High*

*These alarms may be combined with an automatic shutdown system, if fitted. Automatic shutdowns for these items are not to be fitted on emergency engines.

3.5 Remote control for propulsion machinery

3.5.1 The following systems are to be provided with alarms:

System:	*Alarm:*
Operating medium for hydraulic or pneumatic coupling in propulsion system	Low pressure
Operating medium for hydraulic or pneumatic remote control system for main engine	Low pressure
Electrical supply to remote control system for main engine.	Loss of supply

3.6 Controllable pitch propellers and transverse thrust units

3.6.1 Preferred alarms and safeguards are indicated in 3.6.2 to 3.6.4.

3.6.2 In the case of main propulsion systems, means are to be provided to prevent the engines and shafting being subjected to excessive torque due to changes in propeller pitch; alternatively an engine overload indicator may be fitted at each station from which it is possible to control the pitch of the propeller.

3.6.3 Where transverse thrust units are remotely controlled, means are to be provided at the remote control station to stop the propulsion unit.

3.6.4 The following systems are to be provided with alarms:

System:	*Alarm:*
Hydraulic system pressure	Low
Power supply to the control system between the remote control station and hydraulic actuator.	Loss of supply

3.7 Steering gear

3.7.1 For power operated steering gear, safeguards and alarms are to be provided as indicated in 3.7.2 and 3.7.5.

3.7.2 Provision should be made at the bridge to ensure that the steering gear may be rapidly and effectively transferred to an alternative power and control system, which may be manual.

3.7.3 Where the alternative steering gear system is also power operated, this system should be independent of the main power system.

3.7.4 The control system for the alternative steering gear system required by 3.7.2 is to be independent of the main steering gear control system.

3.7.5 The following systems are to be provided with alarms:

System:	*Alarm:*
Steering gear power systems(s)	Failure
Steering gear control systems(s)	Failure
Steering gear hydraulic oil tank level	Low

3.8 Main propulsion shafting

3.8.1 Where a tank supplying lubricating oil to the sternbush is fitted, it is to be located above the load water-line and is to be provided with a low level alarm.

3.9 Liftable wheelhouse systems

3.9.1 For a general description and definitions of Liftable wheelhouse systems, *see* Pt 3, Ch 13,1.

3.9.2 Liftable wheelhouse systems are to be provided with starting and stopping arrangements designed to prevent abrupt accelerations and decelerations when moving the wheelhouse.

3.9.3 Duplicated, independent power supplies, valves, pumps (if required) and hoses to permit emergency lifting and lowering in the event of failure of a duplicated item are to be provided, *see also* 3.9.4.

3.9.4 Easily accessible controls for emergency lifting and lowering is to be provided in the wheelhouse which are to be independent from the main controls.

3.9.5 Cable routing of controls is to be carried out in a reliable way avoiding any possible damage during the operation of the ship or wheelhouse.

3.9.6 Any movement of the wheelhouse is to engage an audible alarm.

3.9.7 Permanent warning notices are to be displayed at accesses to the columns and at control stations indicating potential danger to personnel in the columns due to lifting or lowering movements.

3.9.8 Controls are to be failsafe.

3.9.9 Sufficient cable length should be provided to enable unobstructed movements of the cables when moving the columns. The occurrence of sharp bends in the cables and the possibility of cable damage is to be prevented. Cables are to be suitable for the intended purpose.

■ *Section 4*
Ships operating with unattended machinery spaces

4.1 General

4.1.1 Where it is intended to operate the propulsion machinery and associated systems whilst the machinery space is not continuously attended, the controls and alarms required by Section 3, together with those given in 4.2 to 4.5 are to be provided.

4.2 Alarm system for machinery

4.2.1 An alarm system which will provide warning of faults in the machinery and control systems is to be installed. The system is to satisfy the requirements of 2.3.

4.3 Bridge control for main propulsion machinery

4.3.1 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both ahead and astern directions.

4.3.2 Instrumentation to indicate the following is to be fitted on the bridge:
(a) Propeller speed.
(b) Direction of rotation of propeller for a fixed pitch propeller or pitch position for controllable pitch propeller.
(c) Clutch position where applicable.
(d) Shaft brake position where applicable.

4.3.3 Means of control, independent of the bridge control system, are to be provided on the bridge to enable the watch-keeper to stop the propulsion machinery in an emergency. When the bridge control consists of a system with mechanical linkages only, such an emergency stop system is not required.

4.4 Fire detection alarm system

4.4.1 An automatic fire detection system, together with an audible and visual alarm system is to be fitted in the machinery spaces of Type N Open with flame screens oil tankers, oil and chemical tankers, chemical tankers and lique-fied gas carriers when these ships have a propulsion machinery of 740 kW or more.

4.5 Bilge level alarm system

4.5.1 An alarm is to be provided to warn that liquid in the machinery space bilges has reached a predetermined level. The location of sensors for bilge alarms is to be clearly marked to allow identification by responsible personnel and the sensors are to be provided with means of access for inspection that does not require the use of tools.

■ *Section 5*
Trials

5.1 New or amended installations

5.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the test schedules list as required in 1.2.1.

Section

■ *Section 1* General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to self-propelled and non-self-propelled ships for service on Inland Waterways except where otherwise stated. Attention should also be given to any relevant requirements of National, International or Local Authorities which will apply to the ship in service.

1.1.2 In passenger ships, services essential for safety are to be maintained under emergency conditions and the safety of ship and personnel from electrical hazards is to be assured.

1.1.3 Electrical installations are to be constructed and installed in accordance with the relevant Sections of this Chapter and are to be inspected and tested by the Surveyors. Compliance with the requirements of an acceptable National or International Standard, e.g. Regulations of the A.D.N. (A.D.N.) may be accepted as meeting the requirements of this Chapter, subject to inspection and testing by the Surveyors.

1.1.4 The Committee will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules. Consideration will also be given to the electrical arrangements of small ships and ships to be assigned class notations for a specified limited service.

1.2 Plans

1.2.1 The plans and particulars in 1.2.2 to 1.2.5 are to be submitted, in triplicate, for consideration.

1.2.2 **Electrical equipment**. The arrangement plan and circuit diagram of the switchboard(s). Diagrams of the wiring system including cable sizes, type of insulation, normal working current in the circuits, and the capacity, type and make of protective devices. Calculations of short-circuit currents at main busbars, sub-switchboard busbars and the secondary side of transformers are to be submitted.

1.2.3 **Oil tankers, oil and chemical tankers and chemical tankers**. A general arrangement of the ship showing hazardous zones or spaces and the location of electrical equipment in such zones or spaces. A schedule of safe type electrical equipment located in hazardous zones or spaces giving details of the type of equipment fitted, the certifying Authority, the certificate number and copies of the certificates.

1.2.4 **Prime movers**. *See* Pt 1, Ch 3,12.

1.2.5 **Centralized, bridge or automatic controls**. *See* Chapter 1 and Pt 5, Ch 2.

1.3 Additions or alterations

1.3.1 No addition, temporary or permanent, is to be made to the approved load of an existing installation until it has been ascertained that the current-carrying capacity and the condition of the existing accessories, conductors and switchgear are adequate for the increased load. *See* Pt 1, Ch 3,12.

1.3.2 Plans are to be submitted for approval, and the alterations or additions are to be carried out under the inspection, and to the satisfaction of the Surveyors.

1.4 Application

1.4.1 Except where a specific statement is made to the contrary, all requirements of this Chapter are applicable to both alternating current and direct current installations.

1.4.2 Direct current equipment is to operate satisfactorily under voltage fluctuations of plus six per cent and minus 10 per cent.

1.4.3 Alternating current equipment is to operate satisfactorily under voltage fluctuations of plus six per cent and minus 10 per cent at rated frequency, and under frequency fluctuations of plus or minus five per cent at rated voltage.

1.4.4 Contactors and similar equipment are not to drop out at or above 85 per cent rated voltage.

1.5 Ambient temperatures

1.5.1 The following cooling air and cooling water temperatures are applicable in ships intended for operation in:

(a) **Tropical Zones**
Primary cooling water supply 30°C.
Cooling air temperature 45°C.

(b) **Seasonal Zones**
Vessels intended solely for use in northern or southern waters outside the tropical belt.
Primary cooling water supply 25°C.
Cooling air temperature 40°C.

1.6 Location and construction

1.6.1 Electrical equipment is to be accessibly placed, clear of flammable material in well-ventilated, adequately lighted spaces in which flammable gases cannot accumulate and where it is not exposed to risk of mechanical injury or damage from water, steam or oil. Where necessarily exposed to such risks, the equipment is to be suitably constructed or enclosed. Live parts are to be guarded where necessary.

1.6.2 The operation of all electrical equipment and the lubricating arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice.

1.6.3 All nuts and screws used in connection with the current-carrying parts and working parts are to be effectively locked.

1.7 Earthing

1.7.1 Non-current-carrying metal parts of electrical equipment are to be effectively earthed. Where earthing connections are necessary, they are to be of copper or other approved material and are to be protected against damage and, where necessary, electrolytic action. In general, they are to be equal to the cross-section of the current-carrying conductor up to 16 mm^2. Above this figure they are to be equal to at least half the cross-section of the current-carrying conductor with a minimum of 16 mm^2.

1.7.2 **Portable equipment**. Metal frames of all portable electric lamps, tools and similar apparatus supplied as ship's equipment and rated in excess of 55 V are to be earthed through a suitable conductor unless equivalent safety provisions are made such as by double insulation or by an isolating transformer.

1.8 Creepage and clearance

1.8.1 The distances between live parts and between live parts and earthed metal, whether across surfaces or in air, shall be adequate for the working voltage having regard to the nature of the insulating material and the transient over-voltages developed by switch and fault conditions.

1.9 Electrical equipment for use in explosive gas atmospheres

1.9.1 Where electrical equipment is installed in areas where explosive gas atmospheres may be present, it is to be 'safe type' as defined by IEC 60079: *Electrical Apparatus for Explosive Gas Atmospheres,* or an equivalent national specification.

1.9.2 Copies of type test certificates by a competent independent Testing Authority are to be made available.

1.9.3 For oil tankers, oil and chemical tankers and chemical tankers, *see* Sections 13, 14 and 15.

■ *Section 2* System design – General

2.1 Systems of distribution

2.1.1 The following systems of distribution may be used:

(a) Parallel systems with constant voltage
  (i) d.c., two-wire
  (ii) a.c., single-phase, two-wire
  (iii) a.c., three-phase,
  three-wire
  four-wire with neutral earthed

Systems employing hull return will be accepted except for final sub-circuits which are to be 2-pole insulated.

(b) Series systems with constant current (direct current only).

2.1.2 For parallel systems with constant voltage, system voltages for both alternating current and direct current shall not exceed:

500 V for generation, power, cooking and heating equipment permanently connected to fixed wiring.
250 V for lighting, heaters in cabins and public rooms, and other applications not mentioned above.

2.1.3 Generation and distribution at higher voltages may be submitted for special consideration.

2.2 Earth indication

2.2.1 Every insulated distribution system is to be provided with lamps or other means to indicate the state of insulation to earth.

2.2.2 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits, to continuously monitor the insulation level to earth and to operate an alarm in the event of an abnormally low level of insulation resistance.

2.3 Number and rating of generating sets

2.3.1 The number and rating of the ship's service generating sets and converting sets are to be sufficient to ensure the operation of services essential for the propulsion and safety of the ship.

2.3.2 On oil tankers, oil and chemical tankers, chemical tankers, cargo and passenger ships where electrical power is required for essential equipment, the generating plant and converting plant is to be of such capacity that this essential equipment can be operated satisfactorily even with one generating set or converting set out of action.

2.3.3 In alternating current systems requiring standby equipment, *see* 2.3.1, with one generating set out of action, the remaining set(s) are to have sufficient reserve capacity to permit the starting of the largest motor in the ship without causing any motor to stall or any other device to fail due to excessive voltage drop on the system.

2.4 Emergency source of power in passenger ships

2.4.1 All passenger ships are to be provided with an emergency source of electrical power. Location is to be aft of collision bulkhead and A60 seperated from main generators and in a watertight separated compartment when available.

2.4.2 Where emergency generating sets are fitted, they are to be capable of being started readily when cold.

2.4.3 If hand starting is demonstrated to be practicable, alternative means of starting are not required. Where hand starting is not practicable, other means are to be provided and, in general, should provide for not less than 12 starts in a period of 30 minutes without recourse to sources within the machinery space.

2.4.4 The power available is to be sufficient to supply all services necessary for the safety of passengers and crew in an emergency, due regard being paid to such services as may have to be operated simultaneously. Special consideration is to be given to emergency lighting in all alleyways, stairways and exits, in the machinery spaces and in the control stations (i.e. spaces in which radio, main navigating or central fire recording equipment or the emergency generator is located), to fire detection and alarm systems, to the emergency fire pump if electrically driven, automatic sprinkler systems, if fitted, and to navigation lights. The power is to be adequate for a period of three hours.

2.4.5 The emergency source of power is to be either:

(a) A generator driven by a suitable prime mover with an independent fuel supply and with satisfactory starting arrangements; the fuel used is to have a flash point of not less than 43°C; or
(b) An accumulator (storage) battery capable of carrying the emergency load without recharging or excessive voltage drop.

2.4.6 Where the emergency source of power is an accumulator battery, arrangements are to be such that emergency lighting will automatically come into operation on failure of the main lighting supply.

2.4.7 An indicator is to be mounted in the machinery space, or in the wheelhouse, to indicate when any accumulator battery fitted in accordance with 2.4.5 is being discharged.

2.4.8 The emergency switchboard is to be installed as near as is practicable to the emergency source of power.

2.4.9 The emergency switchboard may be supplied from the main switchboard during normal operation.

2.4.10 Emergency source/distribution is to be independent from main source/distribution and main source/distribution is to be independent of emergency source/distribution.

2.5 Diversity factor

2.5.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connected load before application of any diversity factor.

2.5.2 The diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear.

2.6 Motor circuits

2.6.1 A separate final sub-circuit is to be provided for every motor required for essential services.

2.7 Lighting circuits

2.7.1 Lighting circuits are to be supplied by final sub-circuits separate from those for heating and power. (This does not apply to cabin fans and wardrobe heaters).

2.7.2 A final sub-circuit of rating exceeding 15 A is not to supply more than one point. The number of lighting points supplied by a final sub-circuit of rating 15 A or less is not to exceed:

10 for 24 – 55 V circuits,
14 for 110 – 127 V circuits,
18 for 220 – 250 V circuits,

except that in final sub-circuits for cornice lighting, panel lighting and electric signs where lampholders are closely grouped, the number of points supplied is unrestricted, provided the maximum operating current in the sub-circuit does not exceed 10 A.

2.7.3 Lighting of cargo spaces is to be controlled by multi-pole linked switches situated outside these spaces. Provision is to be made for the complete isolation of these circuits and locking in the off position of the means of control.

2.7.4 Emergency lighting is to be fitted in accordance with 2.4.4.

2.8 Steering gear

2.8.1 Where electrical control of the steering system is fitted, an independent alternative control system is to be installed. This may be a duplicate electrical control system or control by other means.

2.8.2 Provision should be made on the bridge to effectively transfer the steering control instantaneously to the alternative means of control.

2.8.3 Indicators for running indication of steering gear motors are to be installed on the bridge.

2.8.4 Audible and visual alarms are to operate at the steering position(s) for the following fault conditions:
(a) Failure of steering gear power system(s).
(b) Failure of steering gear control system(s).

2.9 Fire detection, alarm and extinguishing systems on passenger ships

2.9.1 Where electrically driven emergency fire pumps are installed in accordance with 17.4.1, the supply to such pumps is not to pass through the main machinery spaces.

2.9.2 Any fire-alarm system is to operate both audible and visual signals at the fire detection control station(s).

2.10 Navigation lights

2.10.1 Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuit-breaker mounted in the distribution board.

2.10.2 Automatic indication of failure is to be provided unless lights are visible from the bridge.

2.10.3 Any Statutory Requirements of the country of registration are to be complied with and may be accepted as an alternative to the above.

2.11 Remote stops for ventilating fans and pumps

2.11.1 Means are to be provided for stopping ventilating fans serving machinery and cargo spaces. These means are to be capable of being operated from outside such spaces in case of fire.

2.11.2 Machinery driving boiler fans, independently driven pumps delivering oil to main propulsion machinery for bearing lubrication and piston cooling, oil fuel transfer pumps and other similar fuel pumps are to be fitted with remote controls situated outside the space concerned so that they may be stopped in the event of fire arising in the space in which they are located.

2.11.3 In passenger ships, all power ventilation systems, except cargo and machinery space ventilation, which is to be in accordance with 2.11.1, are to be fitted with master controls so that all fans may be stopped from either of two separate positions which are to be situated as far apart as practicable.

2.12 Motor control

2.12.1 Every electric motor is to be provided with efficient means of starting and stopping so placed as to be easily operated by the person controlling the motor. Every motor above 0,5 kW is to be provided with control apparatus as given in 2.12.2 to 2.12.6.

2.12.2 Means are to be provided to prevent undesired restarting after a stoppage due to low volts or complete loss of volts. This does not apply to motors, the continuous availability of which is essential to the safety of the ship.

2.12.3 Efficient means of isolation are to be provided so that all voltage may be cut off from the motor and any associated apparatus including any automatic circuit-breaker.

2.12.4 Where the primary means of isolation (that provided at the switchboard, section board or distribution fuse board) is remote from a motor, one of the following is to be provided:
(a) An additional means of isolation fitted adjacent to the motor; or
(b) provision made for locking the primary means of isolation in the OFF position; or
(c) provision made so that the fuses in each line can be readily removed and retained by authorized personnel.

2.12.5 Means are to be provided for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor.

2.12.6 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor against unacceptable overload in the case of single phasing.

2.12.7 When motor control gear is being selected, the maximum current of a motor is to be taken as the full load rated current of the motor.

2.13 Size of batteries and charging facilities

2.13.1 Where batteries are used for starting main engines, they are to be of adequate capacity to meet the requirements of Pt 5, Ch 2,8.

2.13.2 Adequate charging facilities are to be provided, and where batteries are charged from line voltage, by means of a series resistor, protection against reversal of current is to be provided when the charging voltage is 20 per cent of line voltage or higher.

2.13.3 In direct current systems, means are to be provided to isolate the batteries from the low voltage system when being charged from a higher voltage system.

2.14 Communications

2.14.1 For the requirements of the provision of a communication system on board passenger ships, *see* 9.4.4, 17.5 and 17.6.

2.15 Heating and cooking equipment

2.15.1 Each item of heating or cooking equipment is to be controlled as a complete unit by a multi-pole linked switch mounted in the vicinity of the equipment. In the case of cabin heaters a single-pole switch will be acceptable.

2.16 Shore supply

2.16.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a suitable connection box is to be installed in a position in the ship suitable for the convenient connection of flexible cables from the external source and containing a circuit-breaker or isolating switch and fuses and terminals of ample size and suitable shape to facilitate a satisfactory connection. Suitable cables, permanently fixed, are to be provided connecting the terminals to a linked switch and/or a circuit-breaker at the main switchboard.

2.16.2 An earth terminal is to be provided for connecting the hull to the shore earth.

2.16.3 The shore connection is to be provided with an indicator at the main switchboard in order to show when the cable is energized.

2.16.4 Means are to be provided for checking the polarity (for direct current) or the phase sequence (for three – phase alternating current) of the incoming supply in relation to the ship's system.

2.16.5 At the connection box, a notice is to be provided giving full information on the system of supply and the normal voltage (and frequency, if alternating current) of the ship's system and the procedure for carrying out the connection.

2.16.6 Alternative arrangements may be submitted for consideration.

2.17 Choice of cables

2.17.1 Cables are to be in accordance with an acceptable National or International Standard, due regard being given to the ambient conditions stated in 1.5.1.

2.17.2 The rated voltage of any cable is to be not lower than the nominal voltage of the circuit for which it is used.

2.18 Choice of insulating material

2.18.1 The rated operating temperature of the insulating material is to be at least 10°C higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

2.19 Choice of protective covering

2.19.1 Cables fitted in the following locations:
Decks exposed to the weather
Bathrooms
Cargo holds
Machinery spaces
or in any other location where water condensation or harmful vapour (e.g. oil vapour) may be present are to have an impervious sheath. In permanently wet situations, metallic sheaths are to be used for cables with hygroscopic insulation.

2.19.2 All cables are to be of flame-retardant or of fire-resisting type, except that flame-extending cables may be used for final circuits where cables are installed in metallic conduits having an internal diameter not exceeding 25 mm and provided the conduits are mechanically and electrically continuous.

2.20 Current rating

2.20.1 The highest continuous load carried by a cable is not to exceed its current rating. The diversity factor of the individual loads and the duration of the maximum demand may be allowed for in estimating the maximum continuous load and is to be shown on plans submitted for approval.

2.20.2 The voltage drop from the main switchboard busbars to any point in the installation when the cables are carrying maximum current under normal conditions of service, is not to exceed six per cent of the nominal voltage.

2.20.3 In assessing the current rating of lighting circuits, every lampholder is to be assessed at the maximum load likely to be connected to it, with a minimum of 60 W, unless the fitting is so connected as to take only a lamp rated at less than 60 W.

2.20.4 Cables supplying cargo winches, cranes, windlasses and capstans are to be suitably rated for their duty. Unless the duty is such as to require a longer time rating, cables for winch or crane motors may be half hour rated on the basis of the half hour kW rating of the motors. Cables for windlass and capstan motors are to be not less than one hour rated on the basis of the one hour kW rating of the motor. In all cases the rating is to be subject to the voltage drop being within the specified limits.

2.20.5 The current ratings given in Tables 2.2.2 to 2.2.6 are based on maximum operating conductor temperatures given in Table 2.2.1. Alternatively, current rating in accordance with an acceptable National or International Standard may be applied, *see* 2.17.1.

Table 2.2.1 Maximum operating conductor temperature

Insulating material	Maximum rated conductor temperature, °C
ELASTOMERIC COMPOUNDS	
Natural or synthetic rubber (general purpose)	60
Butyl rubber	80
Ethylene propylene rubber	85
Cross-linked polyethylene	85
Silicone rubber	95
THERMOPLASTIC COMPOUNDS	
Polyvinyl chloride (general purpose)	60
Polyvinyl chloride (heat resisting quality)	75
OTHER MATERIALS	
Mineral	95

NOTES
1. Silicone rubber and mineral insulation may be used for higher temperatures (to 150°C for silicone rubber, unlimited for mineral insulation) when installed where they are not liable to be touched by ship's personnel. Proposals to employ these higher temperatures will be specially considered.
2. The temperature of the conductor is the combination of ambient temperature and temperature rise due to load.

2.21 Correction factors for current rating

2.21.1 **Ambient temperature**. When it is known that the ambient temperature is different from that given in 1.5, correction factors shown in Table 2.2.7 are to be applied.

2.21.2 **Intermittent service**. Where the load is intermittent, the correction factors in Table 2.2.8 may be applied for half hour and one hour ratings. In no case is a shorter rating than one half hour rating to be used, whatever the degree of intermittency.

Table 2.2.2 General purpose rubber and PVC

Nominal cross-section	Current rating (Based on ambient temp. 40°C) Single core		2 core		3 or 4 core	
mm^2	amperes		amperes		amperes	
1	9		8		7	
1,5	14		12		9	
2,5	20		16		14	
4	25		22		17	
6	33		29		23	
10	46		39		32	
16	62		53		43	
25	82		69		56	
35	100		85		70	
50	121		102		84	
60	138		115		97	
70	155		132		108	
95	190		161		132	
120	219		185		153	
150	253		215		177	
185	288		244		201	
240	336		283		234	
300	385		328		269	
	d.c.	a.c.	d.c.	a.c.	d.c.	a.c.
400	449	437	380	374	316	311
500	518	495	437	420	363	345
625	598	541	506	432	414	380

Table 2.2.3 Heat resisting PVC

Nominal cross-section	Current rating (Based on ambient temp. 40°C) Single core		2 core		3 or 4 core	
mm^2	amperes		amperes		amperes	
1	14		12		10	
1,5	18		15		13	
2,5	26		22		18	
4	35		29		24	
6	44		38		31	
10	62		53		43	
16	82		69		57	
25	108		93		77	
35	135		113		95	
50	162		137		113	
60	189		162		135	
70	205		174		144	
95	248		211		174	
120	292		248		205	
150	335		286		232	
185	378		324		265	
240	448		383		313	
300	513		436		359	
	d.c.	a.c.	d.c.	a.c.	d.c.	a.c.
400	616	605	524	513	432	421
500	702	670	594	572	491	470
625	799	724	680	616	562	508

Table 2.2.4 Butyl

Nominal cross-section	Current rating (Based on ambient temp. 40°C) Single core		2 core		3 or 4 core	
mm^2	amperes		amperes		amperes	
1	16		13		11	
1,5	20		17		14	
2,5	28		24		19	
4	37		32		27	
6	48		41		34	
10	67		57		47	
16	90		76		63	
25	118		96		82	
35	150		127		105	
50	177		150		123	
60	198		171		139	
70	230		196		161	
95	278		235		195	
120	321		273		225	
150	364		310		255	
185	417		355		292	
240	492		417		345	
300	567		482		396	
	d.c.	a.c.	d.c.	a.c.	d.c.	a.c.
400	653	631	556	535	455	444
500	739	685	631	589	519	482
625	845	739	728	621	589	514

Table 2.2.5 Ethylene propylene rubber, cross-linked polyethylene

Nominal cross-section	Current rating (Based on ambient temp. 40°C) Single core		2 core		3 or 4 core	
mm^2	amperes		amperes		amperes	
1	17		14		12	
1,5	21		18		15	
2,5	30		24		20	
4	40		34		28	
6	51		42		35	
10	71		60		50	
16	95		81		67	
25	127		108		89	
35	154		127		106	
50	191		164		133	
60	212		180		148	
70	239		202		166	
95	292		248		205	
120	339		294		237	
150	387		329		270	
185	440		373		307	
240	519		441		364	
300	594		505		416	
	d.c.	a.c.	d.c.	a.c.	d.c.	a.c.
400	689	668	583	572	482	466
500	784	731	668	625	551	509
625	901	774	763	657	625	541

Table 2.2.6 Silicone rubber, mineral

Nominal cross-section	Current rating (Based on ambient temp. 40°C) Single core	2 core	3 or 4 core
mm^2	amperes	amperes	amperes
1	21	18	15
1,5	25	21	18
2,5	34	28	23
4	44	38	30
6	58	49	36
10	79	67	55
16	105	89	74
25	142	121	99
35	173	147	121
50	210	184	152
60	242	205	168
70	268	228	188
95	325	278	226
120	378	320	263
150	431	368	301
185	494	420	345
240	599	509	420
300	693	588	483

Table 2.2.7 Correction factors for ambient temperature

Insulation	Correction factor for ambient temperature 40°C	45°C	50°C	55°C
Rubber or PVC (general purpose)	1,00	0,87	0,71	—
PVC (heat-resisting quality)	1,00	0,93	0,84	0,76
Butyl rubber	1,00	0,93	0,84	0,80
Ethylene propylene rubber, cross linked polyethylene	1,00	0,94	0,89	0,82
Mineral, silicone rubber	1,00	0,95	0,90	0,85

Table 2.2.8 Correction factors for intermettent service

Correction factor	Half-hour rating With metallic sheath	Half-hour rating Without metallic sheath	One hour rating With metallic sheath	One hour rating Without metallic sheath
	mm^2	mm^2	mm^2	mm^2
1,0	Up to 20	Up to 75	Up to 67	Up to 230
1,1	21 – 40	76 – 125	68 – 170	231 – 400
1,15	41 – 65	126 – 180	171 – 290	401 – 600
1,2	66 – 95	181 – 250	291 – 430	–
1,25	96 – 130	251 – 320	431 – 600	–
1,3	131 – 170	321 – 400	–	–
1,35	171 – 220	401 – 500	–	–
1,4	221 – 270	–	–	–

2.22 Arrangement of cables

2.22.1 Cables having insulating materials with different maximum-rated conductor temperatures are not to be bunched together, or where this is not practicable, the cables are to be so operated that no cable reaches a temperature higher than that permitted for the lowest temperature-rated cable in the group.

2.23 Connections between entrained ships

2.23.1 Cables are to be suitable for use in the connections between entrained ships, i.e. are to be flexible, robust and of commensurate cross-section area.

2.23.2 The connection is to include provisions for the continuity of out-of-balance or earth-fault current return. The connecting device is to include provisions to ensure that this circuit is closed before, and opened after, the live circuits.

2.23.3 Terminal plugs and sockets, if used, are to be so arranged that any exposed pins cannot be energized, *see* 10.3 for additional requirements.

2.23.4 Where hull-return systems are used, hull polarity is to be compatible.

■ *Section 3* System design – Protection

3.1 General

3.1.1 Installations are to be protected against accidental overcurrents including short-circuit. The protective devices are to provide complete and co-ordinated protection to ensure:

(a) Continuity of service under fault conditions through discriminative action of the protective devices.
(b) Elimination of the fault to reduce damage to the system and hazard of fire.

3.2 Protection against overload

3.2.1 Circuit-breakers and automatic switches provided for overload protection are to have tripping characteristics appropriate to the system. Fuses above 320 A are not to be used for overload protection, but may be used for short-circuit protection.

3.3 Protection against short-circuit

3.3.1 Protection against short-circuit currents is to be provided.

3.3.2 The breaking capacity of every protective device is to be not less than the maximum value of the short-circuit current which can flow at the point of installation at the instant of contact separation.

3.3.3 The making capacity of every switching device intended to be capable of being closed, if necessary, on short-circuit, is to be not less than the maximum value of the short-circuit current at the point of installation. On alternating current, this maximum value corresponds to the peak value allowing for maximum asymmetry.

3.3.4 Every protective device or contactor not intended for short-circuit interruption is to be adequate for the maximum short-circuit current which can occur at the point of installation having regard to the time required for the short-circuit to be removed.

3.3.5 In the absence of precise data, the following short-circuit currents at the machine terminals are to be assumed:

(a) Direct current systems
10 times full load current for generators normally connected (including spare).
Six times full load current for motors simultaneously in service.
(b) Alternating current systems
10 times full load current for generators normally connected (including spare) – symmetrical r.m.s.
Three times full load current for motors simultaneously in service.

3.4 Combined circuit-breakers and fuses

3.4.1 The use of a circuit-breaker of breaking capacity less than the prospective short-circuit current at the point of installation is permitted, provided that it is preceded on the generator side by fuses, or by a circuit-breaker having at least the necessary breaking capacity. The generator breakers are not to be used for this purpose.

3.4.2 Fused circuit-breakers with fuses connected to the load side may be used where operation of the circuit-breaker and fuses is co-ordinated.

3.4.3 The characteristics of the arrangement shall be such that:

(a) When the short-circuit current is broken, the circuit-breaker on the load side shall not be damaged and is to be capable of further service.
(b) When the circuit-breaker is closed on the short-circuit current, the remainder of the installation shall not be damaged. However, it is admissible that the circuit-breaker on the load side may require servicing after the fault has been cleared.

3.5 Protection of circuits

3.5.1 Short-circuit protection is to be provided in each live pole of a direct current system and in each phase of an alternating current system.

3.5.2 Overload protection is to be provided in:

(a) Two-wire direct current or single-phase alternating current system – at least one line or phase.
(b) Three-wire direct current system – both outer lines.
(c) Insulated three-phase alternating current system – at least two phases.
(d) Earthed three-phase alternating current system – all three phases.

3.5.3 No fuse, non-linked switch or non-linked circuit-breaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors.

3.5.4 These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

3.6 Protection of generators

3.6.1 In addition to the protection required by 3.5.1 and 3.5.2, protective gear required by 3.6.2 to 3.6.4, is to be provided as a minimum.

3.6.2 For generators not arranged to run in parallel: A circuit-breaker or contactor arranged to open simultaneously all insulated poles or in the case of generators rated at less than 50 kW a multi-pole linked switch with a fuse in each insulated pole.

3.6.3 For generators arranged to operate in parallel: A circuit-breaker or contactor arranged to open simultaneously all insulated poles and provided with:

(a) For direct current generators, instantaneous reverse-current protection operating at not more than 15 per cent rated current.
(b) For alternating current generators, a reverse-power protection, with time delay, selected and set within the limits of two per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover.

3.6.4 The reverse-current protection is to be adequate to deal with the reverse-current conditions emanating from the ship's network, e.g. winches.

3.7 Feeder circuits

3.7.1 Isolation and protection of each main distribution circuit is to be ensured by a multi-pole circuit breaker or switch and fuses. Protection is to be in accordance with 3.2, 3.3 and 3.5. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

3.7.2 Circuits which supply motors fitted with overload protection may be provided with short-circuit protection only.

3.7.3 Motors of rating exceeding 0,5 kW are to be protected individually against overload and short-circuit. The short-circuit protection can be provided by the same protective device for the motor and its supply cable. The overload protection may be replaced by an overload alarm if desired by the Owner.

3.8 Power transformers

3.8.1 The primary circuits of power transformers are to be protected against short-circuit by circuit-breakers or fuses.

3.8.2 When transformers are arranged to operate in parallel, means of isolation are to be provided on the secondary windings. Switches and circuit-breakers are to be capable of withstanding surge currents.

3.9 Lighting circuits

3.9.1 Lighting circuits are to be provided with overload and short-circuit protection.

3.9.2 Where more than one light is installed in a space, the lighting is to be supplied from at least two final sub-circuits in such a way that failure of one of the circuits does not leave the space in darkness.

3.10 Meters, pilot lamps, capacitors

3.10.1 Protection is to be provided for voltmeters, voltage coils of measuring instruments, earth indicating devices and pilot lamps, together with their connecting leads.

3.10.2 A pilot lamp installed as an integral part of another item of equipment need not be individually protected, provided it is fitted in the same enclosure.

3.11 Batteries

3.11.1 Batteries, except starter batteries, are to be protected against short-circuit by a fuse in each insulated conductor or a multi-pole circuit-breaker at a position adjacent to the battery compartment.

■ *Section 4* Rotating machines

4.1 General

4.1.1 Rotating machines are to be constructed in accordance with an acceptable National or International Standard, due regard being given to the ambient conditions stated in 1.5.

4.2 Rating

4.2.1 Ships' service generators, including their exciters, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air or water temperature for an unlimited period, without the limits of temperature rise in 4.3 being exceeded. Other generators and motors are to be rated in accordance with the duty which they are to perform, and when tested under rated load conditions the temperature rise is not to exceed the values in 4.3. Alternatively, limits of temperature rise in accordance with an acceptable National or International Standard may be applied, *see* 4.1.1.

4.3 Temperature rise

4.3.1 Table 2.4.1 gives the limits of temperature rise above the cooling air temperature, calculated on the basis of a cooling air temperature not exceeding 40°C.

4.3.2 For machines intended to operate in ships intended for operation in tropical zones, as defined in 1.5, the temperature rises given should be reduced by 5°C for all machines.

4.3.3 If it is known that the temperature of the cooling air exceeds the values given in 1.5, the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling air.

4.4 Direct current service generators

4.4.1 Automatic voltage regulators are to be provided for shunt wound direct current generators.

4.4.2 Direct current generators used for charging batteries without series-regulating resistors are to be either:
(a) shunt-wound; or
(b) compound-wound with switches arranged so that the series winding can be switched out of service.

4.4.3 Means are to be provided at the switchboard to enable the voltage of generators required to run in parallel to be adjusted separately.

4.4.4 For each direct current generator, coupled to its prime mover, at any temperature within the working range, the means required by 4.4.3 is to be capable of adjusting the voltage at any load between no load and full load to within:
(a) 0,5 per cent of rated voltage for generators of rating exceeding 100 kW; and
(b) 1,0 per cent of rated voltage for generators of rating not exceeding 100 kW.

4.4.5 The inherent Regulation of ships' service generators is to be such that the following conditions are satisfied:
(a) For shunt or stabilized shunt-wound generators, when the voltage has been set at full load, the steady voltage at no load shall not exceed 115 per cent of the full load value, and the voltage obtained at any intermediate value of load shall not exceed the no load value.
(b) For compound-wound generators with the generator at full load operating temperature, and starting at 20 per cent load with voltage within one per cent of rated voltage, then at full load the voltage is to be within 2,5 per cent of rated voltage. The average of the ascending and descending load/voltage curves between 20 per cent load and full load is not to vary more than four per cent from rated voltage.

4.4.6 Generators are to be capable of delivering continuously the full load current and normal rated voltage at the terminals when running at full load engine speed at all ambient temperatures up to the specified maximum.

4.4.7 Generators required to run in parallel are to be stable from no load up to the total combined load of the group, and load sharing is to be satisfactory.

4.4.8 The series winding of each two-wire generator is to be connected to the negative terminal.

4.4.9 Equalizer connections are to have a cross-sectional area appropriate to the system but in no case less than 50 per cent of that of the negative connection from the generator to the switchboard.

4.5 Alternating current service generators

4.5.1 Each alternating current service generator, unless of the self-regulating type, is to be operated in conjunction with a separate automatic voltage regulator.

4.5.2 The voltage regulation of any alternating current generator with its AVR is to be such that at all loads from zero to full load the rated voltage at rated power factor is maintained under steady conditions within ±2,5 per cent.

4.5.3 Alternating current generators required to run in parallel are to be stable from 20 per cent full load (kW) up to the total combined full load (kW) of the group, and load sharing is to be satisfactory. The facilities for adjusting the governor of an alternating current generating set, at normal frequency, are to be sufficiently fine to permit an adjustment of load on the prime mover to within five per cent of full load.

4.5.4 When generators are operated in parallel, the kVA loads of the individual generating sets are not to differ from their proportionate share of the total kVA load by more than five per cent of the rated kVA output of the largest machine when operating at 0,8 power factor.

4.6 Inspection and testing

4.6.1 On machines for essential services, tests are to be carried out in accordance with the relevant standard and a certificate furnished by the manufacturer.

4.6.2 Generators and motors of 100 kW or over intended for essential services are to be inspected by the Surveyors during manufacture and testing.

Table 2.4.1 Temperature rise in °C calculated on the basis of a cooling air temperature not exceeding 40°C

Limits of temperature rise of machines cooled by air, °C						
Part of machine	Method of temperature measurement	Insulation class				
		A	E	B	F	H
1. (a) a.c. windings of machines having output of 5000 kVA or more	ETD R	60 55	— —	80 75	100 95	120 115
(b) a.c. windings of machines having output of less than 5000 kVA	ETD R	60 55	— 70	85 75	105 100	120 115
2. Windings of armatures having commutators	R T	55 45	70 60	75 65	100 80	120 100
3. Field windings of a.c. and d.c. machines having d.c. excitation other than those in item 4	R T	55 45	70 60	75 65	100 80	120 100
4. (a) Field windings of synchronous machines with cylindrical rotors having d.c. excitation	R	—	—	85	105	130
(b) Stationary field windings of d.c. machines having more than one layer	R T	55 45	70 60	75 65	100 80	120 100
(c) Low resistance field windings of a.c. and d.c. machine and compensating windings of d.c. machines having more than one layer	R,T	55	70	75	95	120
(d) Single-layer windings of a.c. and d.c. machines with exposed bare or varnished metal surfaces and single-layer compensating windings of d.c. machines	R,T	60	75	85	105	130
5. Permanently short-circuited insulated windings	T	55	70	75	95	120
6. Permanently short-circuited uninsulated windings	T	The temperature rise of these parts shall in no case reach such a value that there is a risk to any insulation or other materials on adjacent parts or to the item itself				
7. Magnetic cores and other parts not in contact with windings	T					
8. Magnetic cores and other parts in contact with windings	T	55	70	75	95	115
9. Commutators and slip-rings open and enclosed	T	55	65	75	85	95

NOTES
1. Where water cooled heat exchangers are used in the machine cooling circuit, the temperature rises are to be measured with respect to the temperature of the cooling water at the inlet to the heat exchanger and the temperature rises given in Table 2.4.1 shall be increased by 10°C provided the inlet water temperature does not exceed the values given in 1.5.
2. T = thermometer method
R = resistance method
ETD = embedded temperature detector
3. Temperature rise measurements are to use the resistance method whenever practicable.
4. The ETD method may only be used when the ETDs are located between coil sides in the slot.

Section 5
Switchgear assemblies, switchgear and fusegear – Construction and testing

5.1 Switchgear assemblies

5.1.1 Switchboards, section boards and distribution boards are to be so installed that live parts are sufficiently guarded and adequate space is provided for maintenance, also they are to be protected where necessary in way of pipes and to be constructed from, or enclosed with, non-flammable non-hygroscopic material.

5.1.2 All measuring instruments and all apparatus controlling circuits are to be clearly and indelibly labelled for identification purposes. An indelible label is to be permanently secured to, or adjacent to, every fuse and every circuit-breaker, and marked with particulars of the full load current of the generator or cable which the fuse or circuit-breaker protects. Where inverse time limit and/or reverse current devices are provided in connection with a circuit-breaker, the appropriate settings of these devices are to be stated on the label. Nameplates are to be of flame-retardant material.

5.2 Instruments

5.2.1 Sufficient instrumentation is to be provided for measuring voltage, current, frequency and power for alternating current generators greater than 50 kW.

5.2.2 Where alternating current generators are required to operate in parallel, synchronizing arrangements are to be fitted.

5.3 Instrument transformers

5.3.1 The secondary windings of instrument transformers are to be earthed.

5.4 Switchgear

5.4.1 Circuit-breakers and switches are to be of the air break type and are to be constructed in accordance with an acceptable National or International Standard.

5.4.2 Reports of tests to establish the capacity of circuit-breakers, are to be submitted for consideration when required.

5.4.3 Overcurrent releases are to be calibrated in amperes, and settings marked on the circuit-breaker.

5.5 Fuses

5.5.1 Fuses are to comply with an acceptable National or International Standard.

5.5.2 Fuse-links and fuse-bases are to be marked with particulars of rated current and rated voltage. Each fuse position is to be permanently and indelibly labelled with the current-carrying capacity of the circuit protected by it and with the appropriate approved size of fuse or replaceable element.

5.6 Testing

5.6.1 Before installation, switchboards complete or in sections with all components, are to pass the following tests at the manufacturer's works and a certificate furnished. A high voltage test is to be carried out on all switching and control apparatus for systems greater than 60 V with a test voltage of 1000 V plus twice the rated voltage (minimum 2000 V) at any frequency between 25 and 100 Hz for one minute applied between:

(a) all current-carrying parts connected together and earth; and
(b) between current-carrying parts of opposite polarity or phase.

5.6.2 For systems of 60 V or less, the test shall be at 500 V for one minute.

5.6.3 Instruments and ancillary apparatus may be disconnected during the high voltage test.

5.6.4 Immediately after the high voltage test, the insulation resistance between:

(a) all current-carrying parts connected together and earth, and
(b) between current-carrying parts of opposite polarity or phase,

shall be not less than one MΩ when tested with a direct current voltage of at least 500 V.

Section 6
Control gear – Construction and testing

6.1 General

6.1.1 Control gear is to comply with an acceptable National or International Standard.

6.1.2 Control gear, including isolating and reversing switches, is to be so arranged that shunt field circuits are not disconnected without an adequate discharge path being provided.

6.2 Testing

6.2.1 Control gear and resistors are to be tested by the makers with a high voltage applied between the earthed frame and all live parts. The test voltage is to be 1000 V plus twice the rated voltage with a minimum of 2000 V. The voltage is to be alternating at any frequency between 25 and 100 Hz and is to be maintained for one minute without failure.

6.2.2 Instruments and auxiliary apparatus may be disconnected during the high voltage test.

6.2.3 Immediately after the high voltage test, the insulation resistance between:
(a) current-carrying parts connected together and earth; and
(b) between current-carrying parts of opposite polarity or phase;
shall be not less than one MΩ when tested with a direct current voltage of at least 500 V.

■ *Section 7* Cables – Construction and testing

7.1 General

7.1.1 Cables are to be in accordance with an acceptable National or International Standard, due regard being given to the ambient conditions stated in 1.5.

7.2 Insulating materials

7.2.1 Permitted insulating materials with maximum rated conductor temperatures are given in Table 2.2.1.

7.2.2 Where a rubber or rubber-like material with maximum conductor temperature greater than 60°C is used, it is to be readily identifiable.

7.2.3 Other insulating materials will be considered.

7.3 Sheaths and protective coverings

7.3.1 Cables are to be protected by one or more of the following, and the sheath or protective covering is to be compatible with the insulation:
(a) Sheath
 Lead-alloy sheath
 Copper sheath
 Non-metallic sheath
(b) Protective covering
 Steel-wire armour
 Steel-tape armour
 Metal-braid armour
 (basket weave)
 Fibrous braid.

7.3.2 Unsheathed cables, e.g. rubber-insulated taped and braided or equivalent, may be used only if installed in conduit.

7.3.3 **Non-metallic sheath**. Polychloroprene compound, polyvinyl chloride compound and chlorosulphonated polyethylene may be used for impervious sheaths. Other compounds will be considered.

7.3.4 **Fibrous braid**. Textile braid is to be of cotton, hemp, glass or other equivalent fibre, and is to be of strength suitable for the size of the cable. It is to be effectively impregnated with a compound which is resistant to moisture, and flame retarding except where flame-extending cables are permitted by 2.19.2.

7.3.5 Cable outer sheath of cables are to be resistant to oil and oil vapour.

7.4 Testing

7.4.1 Tests in accordance with an acceptable National or International Standard are to be made at the manufacturer's works prior to despatch.

■ *Section 8* Transformers – Construction and testing

8.1 General

8.1.1 Transformers are to be in accordance with an acceptable National or International Standard, due regard being given to the ambient conditions stated in 1.5.

8.2 Construction

8.2.1 Transformers, except those for motor starting, are to be double wound.

8.3 Regulation

8.3.1 The inherent regulation at 0,8 power factor is not to exceed five per cent.

8.3.2 Regulation of the complete system is to comply with 2.20.2.

8.4 Short-circuit

8.4.1 All transformers are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding for two seconds.

8.5 Tests

8.5.1 Transformers for essential services are to be tested by the manufacturers in accordance with the relevant standard and test certificates supplied.

■ *Section 9* Batteries – Construction and testing

9.1 Construction

9.1.1 The cells of all batteries are to be so constructed and secured as to prevent spilling of the electrolyte due to the motion of the ship, and to prevent emission of acid or alkaline spray.

9.2 Supports

9.2.1 Batteries are to be so arranged that each cell or crate of cells is accessible from the top and at least one side.

9.2.2 Cells or crates are to be carried on non-absorbent insulating supports. Similar insulators are to be fitted to prevent any movement of cells arising from the motion of the ship.

■ *Section 10* Accessories – Construction and testing

10.1 Enclosures

10.1.1 Enclosures are to be of metal or of flame-retardant insulating materials.

10.2 Inspection and draw boxes

10.2.1 If metal conduit systems are used, inspection and draw boxes are to be of metal and are to be in rigid electrical and mechanical connection with the conduits.

10.3 Socket outlets and plugs

10.3.1 Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

10.3.2 All socket outlets of current rating 15 A or more are to be provided with a switch.

■ *Section 11* Heating and cooking equipment

11.1 Construction and testing

11.1.1 Heaters are to be so constructed, installed and protected that clothing, bedding and other flammable material cannot come in contact with them in such a manner as to cause risk of fire. There is to be no excessive heating of adjacent bulkheads or decks.

■ *Section 12* Installation of equipment

12.1 Cables

12.1.1 Cable runs are to be, as far as possible, straight and accessible.

12.1.2 Cables having insulating materials with different maximum-rated conductor temperatures are not to be bunched together, or, where this is not practicable, the cables are to be operated so that no cable reaches a temperature higher than that permitted for the lowest temperature-rated cable in the group.

12.1.3 Cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

12.1.4 The minimum internal radius or bend of installed cables is to be generally in accordance with:

$4d$ for cables without braiding, armouring or other metal sheath and with an overall diameter not exceeding 25 mm

$6d$ for all other cables

(d = overall diameter of cable).

12.2 Mechanical protection of cables

12.2.1 Cables exposed to risk of mechanical damage are to be protected by metal channels or casing or enclosed in steel conduit unless the protective covering (e.g. armour or sheath) is sufficient to withstand the possible damage.

12.2.2 Cables in cargo holds and other spaces where there is exceptional risk of mechanical damage are to be suitably protected, even if armoured, unless the steel structure affords adequate protection. *See also* 13.6.

12.2.3 Metal casings for mechanical protection of cables are to be efficiently protected against corrosion.

12.3 Earthing of metal coverings

12.3.1 Metal coverings of cables are to be effectively earthed at both ends of the cable, except in final sub-circuits where earthing at the supply end only will be considered adequate. This does not necessarily apply to instrumentation cables where single point earthing may be desirable for technical reasons.

12.3.2 The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tappings, is to be ensured.

12.3.3 The lead sheath of lead-sheathed cables is not to be used as the sole means of earthing the non-current carrying parts of items of equipment.

12.4 Securing of cables

12.4.1 Cables are to be effectively supported and secured without their coverings being damaged.

12.4.2 The distances between supports is to be chosen according to the type of cable.

12.4.3 Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection.

12.5 Penetration of bulkheads and decks by cables

12.5.1 Penetration of watertight bulkheads or decks is to be carried out with either individual watertight glands or with packed watertight boxes carrying several cables. However carried out, the watertight integrity of the bulkheads or decks is to be maintained.

12.5.2 Cables passing through decks are to be protected by deck tubes or ducts.

12.5.3 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with lead or other approved material. If the steel is at least 6 mm thick, adequately rounded edges may be accepted as the equivalent of bushing.

12.5.4 Materials used for glands and bushings are to be such that there is no risk of corrosion.

12.5.5 Where rectangular holes are cut in bulkheads or structural steel, the corners are to be radiused.

12.6 Installation of cables in pipes and conduits

12.6.1 Metal conduit systems are to be earthed and are to be mechanically and electrically continuous across joints. Individual short lengths of conduit need not be earthed.

12.6.2 The internal radius of bend of pipes and conduit is to be not less than that laid down for cables, provided that for pipes exceeding 64 mm diameter, the internal radius of bend is not less than twice the diameter of the pipe.

12.6.3 The drawing-in factor (ratio of the sum of the cross-sectional areas of the cables to the internal cross-section area of the pipe) is not to exceed 0,4.

12.6.4 Expansion joints are to be provided where necessary.

12.6.5 Where necessary, ventilation openings are to be provided at the highest and lowest points to permit air circulation and to prevent accumulation of water.

12.6.6 Where cables are laid in trunks, the trunks are to be so constructed as not to afford passage for fire from one ‘tween deck or compartment to another.

12.6.7 Non-metallic ducting or conduit is to be of flame retardant material. PVC conduit is not to be used in refrigerated spaces or on open decks, unless specially approved.

12.7 Cables for alternating current

12.7.1 Where it is necessary to use single-core cables for alternating current circuits rated in excess of 20 A, the requirements of 12.7.2 to 12.7.7 are to be complied with.

12.7.2 Cables are to be either non-armoured or armoured with non-magnetic material.

12.7.3 If installed in pipe or conduit, cables belonging to the same circuit are to be installed in the same conduit, unless the conduit or pipe is of non-magnetic material.

12.7.4 Cable clips are to include cables of all phases of a circuit unless the clips are of non-magnetic material.

12.7.5 In the installation of two, three or four single-core cables forming respectively single-phase circuits, three-phase circuits or three-phase and neutral circuits, the cables are to be in contact with one another, as far as possible. In any event the distance between adjacent cables is not to be greater than one diameter.

12.7.6 If single-core cables of current rating greater than 250 A are run along a steel bulkhead. Wherever practicable, the cables should be spaced away from the steel.

12.7.7 Where single-core cables of rating exceeding 50 A are used, magnetic material is not to be placed between single-core cables of a group. If these cables pass through steel plates, all cables of the same circuit are to pass through a plate or gland so constructed that there is no magnetic material between the cables, and suitable clearance is provided between the cable core and magnetic material. This clearance, wherever practicable, is to be not less than 75 mm when the current exceeds 300 A. For currents between 50 A and 300 A, the clearance is to be obtained by interpolation.

12.8 Cable ends

12.8.1 The ends of all conductors or cross-sectional area greater than 4 mm^2 are to be fitted with soldering sockets, compression type sockets or mechanical clamps. Corrosive fluxes are not to be used.

12.8.2 Cables having a hygroscopic insulation (e.g. mineral insulated) are to have their ends sealed against ingress of moisture.

12.8.3 Cables with a supplementary insulating belt beneath the protective sheath are to have additional insulation at those points where the insulation of each core makes or may make contact with earthed metal.

12.9 Joints and branch circuits in cable systems

12.9.1 If a joint is necessary it is to be carried out so that all conductors are adequately secured, insulated and protected from atmospheric action. Terminals or busbars are to be of dimensions adequate for the cable rating.

12.10 Batteries

12.10.1 Alkaline batteries and lead acid batteries are not to be installed in the same compartment.

12.10.2 Large batteries are to be installed in a space assigned to the batteries only or alternatively in a deck box if such a space is not available.

12.10.3 Engine starting batteries are to be located as close as practicable to the engine(s) served. If such batteries cannot be accommodated in the battery room, they are to be installed so that adequate ventilation is ensured.

12.10.4 Where acid is used as the electrolyte, a tray of lead, or wood lined with lead, is to be provided below the cells. Alternatively, the deck below the cells is to be protected with lead or other acid-resisting material which effectually prevents any acid from lodging in contact with the ship's structure.

12.10.5 The interiors of all battery compartments, including shelves, are to be painted with corrosion-resistant paint.

12.10.6 Switches, fuses and other electrical equipment liable to cause an arc are not to be fitted in battery compartments.

12.10.7 Batteries are to be so arranged that each cell or crate of cells is accessible from the top and at least one side.

12.10.8 Cells or crates are to be carried on non-absorbent insulating supports. Similar insulators are to be fitted to prevent any movement of cells arising from the motion of the ship.

12.10.9 Battery compartments are to be ventilated by an independent ventilating system.

12.10.10 Natural ventilation may be employed if ducts can be run directly from the top of the compartment to the open air with no part of the duct more than 45° from the vertical. If natural ventilation is impracticable, mechanical ventilation is to be provided. Interior surfaces of ducts and fans are to be protected against corrosion. Fan motors are not to be located in the air stream.

12.10.11 All openings through the battery compartment bulkheads or decks, other than ventilation openings, are to be effectively sealed to reduce the possibility of escape of gas from the battery compartment into the ship.

12.10.12 Where practicable, battery lockers are to be ventilated in the same manner as battery compartments.

12.10.13 Deck boxes are to be adequately ventilated and means provided to prevent ingress of water.

12.10.14 A permanent notice is to be fitted to all battery compartments prohibiting naked lights and smoking.

12.11 Lighting

12.11.1 Lighting of cargo spaces is to be controlled by multi-pole linked switches situated outside these spaces. Provision is to be made for the complete isolation of these circuits and locking in the OFF position of the means of control.

12.12 Socket outlets and plugs

12.12.1 Where it is necessary to earth the non-current carrying parts of portable or transportable equipment, an effective means of earthing is to be provided at the socket outlet.

12.12.2 In all wet situations, socket outlets and plugs are to be effectively shielded against rain and spray and are to be provided with means of maintaining this quality after removal of the plug.

■ *Section 13*
Special requirements for tankers intended for the carriage in bulk of oil and other hazardous liquids

13.1 General

13.1.1 In addition to the requirements of other relevant Sections, the special requirements of this Section apply to:

(a) Section 14 – Tankers for the carriage in bulk of oil cargoes having a flash point of 55°C and below (closed cup test).

(b) Section 15 – Tankers for the carriage in bulk of other hazardous liquids.

13.2 Earthing and bonding for the control of static electricity

13.2.1 Bonding straps are required for cargo tanks, process plant and piping systems which are not permanently connected to the hull of the ship either directly or via their bolted or welded supports and where the resistance between them and the hull exceeds 1 MΩ.

13.2.2 Where bonding straps are required, they are to be of copper or other approved material, are to be protected against damage and, where necessary, electrolytic action.

13.2.3 Bonding straps are to be installed where they are clearly visible and in an accessible position to allow ease of installation and replacement.

13.3 Systems of supply

13.3.1 The following systems of generation and distribution are acceptable:
(a) d.c., two-wire insulated,
(b) a.c., single-phase, two-wire insulated,
(c) a.c., three-phase, three-wire insulated,
(d) a.c., three-phase, four-wire with neutral solidly earthed but without hull return.

13.4 Distribution

13.4.1 No current carrying part of an insulated distribution system is to be earthed, other than through an earth indicating device or through components used for the suppression of radio interference.

13.5 Fuses

13.5.1 Rewireable type fuses are not to be fitted.

13.6 Cables and cable installation

13.6.1 Electric cables are not to be installed in dangerous zones or spaces, except as permitted in certain paragraphs of this Section or Section 14, or when associated with intrinsically safe circuits.

13.6.2 All cables which may be exposed to cargo oil, oil vapour or gas are to be sheathed with at least one of the following:
(a) Copper sheath (for mineral insulated cable).
(b) Lead alloy sheath plus further mechanical protection, e.g. armour or non-metallic impervious sheath.
(c) Non-metallic impervious sheath plus armour (for mechanical protection and earth detection).

13.6.3 Where corrosion may be expected, non-metallic impervious sheath is to be applied over steel armour.

13.6.4 Cables installed on deck are to be protected against mechanical damage. Cables are to be installed so as to avoid strain or chafing, and due allowance is to be made for expansion or working of the structure. Where expansion bends are fitted, they are to be accessible for maintenance.

13.6.5 Where cables pass through gastight bulkheads or decks, separating dangerous zones or spaces from non-dangerous zones or spaces, arrangements are to be such that the gastight integrity of the bulkhead or deck is not impaired.

13.6.6 Cables installed in pump-rooms are to be suitably protected against mechanical damage.

13.6.7 Cables associated with intrinsically safe circuits are to be used only for such circuits. They are to be physically separated from cables associated with non-intrinsically safe circuits, e.g. neither led on the same casing or pipe nor secured by the same fixing clip.

13.7 Transmitting aerials

13.7.1 Transmitting aerials should be sited well clear of the cargo zone as defined in 13.9.

13.8 Certified safe type equipment

13.8.1 Where reference is made to the following 'safe' types of equipment:
(a) Intrinsically safe (symbol i).
(b) Flameproof (symbol d).
(c) Increased safety (symbol e).
(d) Pressurized enclosure (symbol p).
Such equipment is to be certified for the gases and vapours involved. The construction and type testing is to be in accordance with IEC Publication 60079, *Electrical Apparatus for Explosive Gas Atmospheres*, or an equivalent National Standard. Where it is considered necessary to use certified 'safe' type equipment with protection types non-incendive (symbol n), encapsulated (symbol m), powder filled (symbol p) or special protection (symbol s) details are to be submitted for consideration by LR.

13.8.2 In addition, lighting fittings of the air driven type with a pressurized enclosure are considered to be a 'safe' type of lighting fitting.

13.8.3 When safe type equipment is permitted in dangerous zones or spaces, all switches and protective devices are to interrupt all lines or phases and are to be located in a non-dangerous zone or space unless specifically permitted otherwise. Such equipment, switches and protective devices are to be suitably labelled for identification purposes.

13.9 Dangerous zones or spaces

13.9.1 Dangerous zones or spaces are indicated in Section 14, but the following general principals are to apply:

(a) Spaces containing flammable cargo and all zones or spaces adjacent to cargo tanks are regarded as dangerous zones or spaces.
(b) An enclosed or semi-enclosed space with direct access into a dangerous zone or space is regarded as a dangerous space.
(c) An enclosed space located in a dangerous zone or space may be regarded as a non-dangerous space, provided that it is separated from the flammable liquid cargo by not less than two gastight steel bulkheads or decks, is mechanically ventilated and in addition, has no direct opening into a dangerous zone or space.

13.9.2 Where the ship is designed to allow visits to terminals where the whole ship is regarded as a dangerous zone or space, or the dangerous zones or spaces are otherwise extended, due to the loading terminal height in relation to the associated ship height, this capability is to be identified in the plans required by 1.2.2, including the associated extended dangerous zones or spaces. Electrical equipment and other components that can create sparks that are intended to be used in the extended hazardous areas during loading and discharging are to be of a safe-type or, alternatively, are to have a non-ventilated enclosure of ingress protection rating of at least IP55, or equivalent acceptable to LR.

13.9.3 Where 13.9.2 is applicable, other electrical equipment, and other components that can create sparks, that do not satisfy the constructional requirements of 13.9.2 and are located in the extended dangerous zones or spaces are to be marked red and are to be automatically isolated and shutdown during loading and discharging, *see also* 13.13 and 13.14.

NOTE:
Compliance with the requirements and operating practices of the relevant statutory authorities during visits to such terminals is the responsibility of the Owner.

13.10 Semi-enclosed spaces

13.10.1 Semi-enclosed spaces are considered to be spaces limited by decks and/or bulkheads in such a manner that the natural conditions of ventilation are sensibly different from those obtained on open deck.

13.11 Connections between entrained ships

13.11.1 A suitable earthing connection is to be provided between metalwork of the hulls to ensure equal potential of all entrained ships. These connections, preferably bolted, may be incorporated in the mechanical coupling arrangements, *see* 2.23.

13.12 Electrical apparatus

13.12.1 Where the cargo is liable to damage materials normally used in the construction of electrical apparatus, special consideration is to be given to the materials selected for conductors, insulation and metal parts and/or the protection thereof.

13.13 Spaces maintained at overpressure

13.13.1 Where spaces are maintained at an overpressure to prevent the space being considered a hazardous zone or space, the requirements of this sub-Section are to be complied with.

13.13.2 Arrangements are to be provided to maintain spaces at an overpressure of at least 0,1 kPa relative to external hazardous areas by ventilation from a non-dangerous area.

13.13.3 Air intakes are to be located at least 2 m from hazardous zones and at least 2 m above the deck. Hazardous zones are considered to be:

- The tank deck and spaces up to 3 m above or away from the deck (the tank deck is considered to start from the deck above the cofferdam bulkhead not adjacent to the tank and to extend upwards at an angle of 45° towards the tank to the height of 3 m); and
- zones within a 2 m radius around any pipe, flanged joint or tank opening or glands or other openings through which leakage of cargo oil or other hazardous liquids may occur under normal operating conditions.

In the case of gas or vapour having a relative density of more than 0,75, the hazardous zone is considered to extend vertically downwards.

13.13.4 Electrical equipment, and other components that can create sparks, required to operate upon loss of overpressure or gas detection in spaces maintained at overpressure are to be of a safe-type or, alternatively, are to have a non-ventilated enclosure of ingress protection rating of at least IP55, or equivalent acceptable to LR.

13.13.5 The space pressure is to be monitored continuously and on loss of pressurization:

- equipment in those spaces that does not satisfy the constructional requirements of 13.13.4 is to be automatically isolated; and
- alarms are to be provided in the accommodation to indicate the loss of space pressure.

The arrangements are to prevent automatically isolated equipment being energized until the atmosphere within the space is made safe.

13.13.6 A permanently installed system of gas detection equipment is to be provided in spaces maintained at overpressure and is to satisfy the requirements of 13.13.7 to 13.13.12.

13.13.7 The positions of gas detector heads are to be determined with due regard to the dilution resulting from compartment purging or ventilation and to areas where pockets of gas may accumulate. Due regard is to be given to locating gas detector head at entrances or windows, at ventilation intakes and in appropriate lower positions in spaces where it is intended to carry cargoes with associated gas that is heavier than air.

13.13.8 Gas detection systems are to be suitable for measuring gas resulting from leakage from the intended cargoes of concentrations of 0 to 100 per cent by volume.

13.13.9 Gas detection equipment is to be capable of continuous monitoring. Alternative proposals for sequential detector sampling and analysing may be submitted for consideration where it can be demonstrated that an acceptable level of safety is achieved in all applicable spaces.

13.13.10 When a gas concentration of 20 per cent of the lower explosive limit (LEL) of the gas resulting from leakage from the intended cargoes is detected:

- equipment that does not satisfy the constructional requirements of 13.13.4 is to be automatically isolated in the relevant space(s), *see also* 13.14; and
- alarms are to be provided in the accommodation, wheelhouse, and spaces maintained at overpressure to indicate detection of gas in the relevant space(s).

The arrangements are to prevent automatically isolated electrical equipment being energized until the atmosphere within the space is made safe.

13.13.11 Gas detection equipment is to be so designed that it may be readily tested. Testing and calibration is to be capable of being carried out at regular intervals. Equipment in fan casings is to allow calibration to take into account airflow.

13.13.12 Gas detection systems are to be 'fail-safe', *see also* Pt 6, Ch 1,2.4.6.

13.14 Automatic isolation overrides

13.14.1 Where it would prevent the non-availability of essential services for the propulsion and safety of the ship, arrangements are to be provided on the bridge to allow the overriding of the automatic isolation and shutdown measures required by 13.9.3 and 13.13.10 that can be operated during normal voyage mode, *see also* Pt 6, Ch 1,2.4.9.

■ *Section 14*
Additional requirements for tankers intended for the carriage in bulk of oil cargoes having a flash point of 60°C and below (closed cup test)

14.1 Electrical equipment permitted in dangerous zones or spaces

14.1.1 Sub-Sections 14.2 to 14.6 define the electrical equipment permitted in dangerous zones or spaces.

14.2 Below deck cargo zones

14.2.1 **Cargo tank**. Intrinsically safe electrical equipment.

14.2.2 Cofferdams adjoining cargo tanks:

(a) Intrinsically safe electrical equipment.

(b) Electric depth-sounding devices hermetically enclosed located clear of the cargo tank bulkhead, with cables installed in heavy gauge steel pipe with gastight joints up to the main deck.

(c) Where it is necessary for cables to pass through spaces, other than those supplying the equipment described in this paragraph, they are to be installed in heavy gauge steel pipes with gastight joints.

14.2.3 Cargo pump-rooms:

(a) Electrical equipment as defined in 14.2.2.

(b) **Lighting**. Pump-rooms immediately adjoining an engine room or similar non-dangerous space may be lit through permanently fitted glass lenses or ports fitted in the bulkhead on deck, so arranged as to maintain integrity of the structure. The externally mounted lighting fixture may be designed so that the gastight flanged port forms part of the fixture. The lighting fixtures and wiring are to be located in the non-dangerous space.

(c) Alternatively, flameproof lighting fittings (symbol d) may be fitted. The fittings are to be arranged on at least two independent final branch circuits to permit light from one circuit to be retained while maintenance is carried out on the other.

(d) Lighting fittings of the air driven type, *see* 13.8.2.

(e) **Motors**. Electrical motors driving equipment located in cargo pump-rooms are to be separated from the pump-room by a gastight bulkhead or deck. Flexible couplings or other means of maintaining alignment are to be fitted in the shafts between the motors and the driven unit. In addition, suitable stuffing boxes are to be fitted where shafts pass through gastight bulkheads or decks.

(f) **Cables**. Where it is necessary for cables other than those supplying lighting to pass through cargo pump-rooms, they are to be installed in heavy gauge steel pipes with gastight joints.

14.2.4 Spaces other than cofferdams adjoining and below the top of a cargo tank e.g. holds:
(a) Intrinsically safe equipment.
(b) Safe type lighting fittings, *see* 13.8.
(c) Through runs of cable.
(d) Special consideration is to be given to the mechanical protection of electrical equipment in such spaces.

14.3 Above deck cargo zone

14.3.1 Safe type equipment, *see* 13.8. Such equipment is to be suitably protected for use on deck.

14.3.2 Through runs of cable.

14.4 Adjoining parts of above deck cargo zone

14.4.1 Safe type equipment, *see* 13.8. Such equipment is to be suitably protected for use on deck.

14.4.2 Through runs of cable.

14.5 Enclosed or semi-enclosed spaces having bulkheads in line with cargo tank bulkheads

14.5.1 Safe type equipment, *see* 13.8. Such equipment is to be suitably protected for use on deck where necessary.

14.5.2 Through runs of cable.

14.6 Compartments for cargo hoses

14.6.1 Intrinsically safe equipment.

14.6.2 Safe type lighting fittings, *see* 13.8.

14.6.3 Through runs of cable.

14.7 Cargo tank level, pressure and temperature measurement

14.7.1 Independent 1st stage and 2nd stage high level alarms are to be provided for cargo tanks. The 2nd stage high level alarm is to be set at a maximum tank level of 97,5 per cent. Level indication is also to be provided locally to each tank.

14.7.2 ‘Fail-safe’ arrangements (*see* Pt 6, Ch 1,2.4.6) are to be provided to shutdown loading and discharging pumps and compressors to operate in the event of activation of either high cargo tank level alarm required by 14.7.1.

14.7.3 The high cargo tank level alarms required by 14.7.1 are to be both audible and visual and are to be provided on the wheelhouse and on the tank deck.

14.7.4 Indication of cargo tank pressure and temperature on an analogue display is to be provided in the wheelhouse and at the tank deck for all fluids and gasses where dangerous situations may arise, for example venting resulting from environmental effects causing heating of tanks.

14.7.5 To determine where the dangerous situations referred to in 14.7.4 may arise, reference is to be made to the A.D.N. and the relevant requirements of the appropriate National, International or Local Authorities. The applicability of 14.7.4 is to be identified in the in the plans required by 1.2.2.

14.8 Loading and discharging pump control

14.8.1 Cargo pumps are to be provided with means to stop the pumps in an emergency in the wheelhouse and at appropriate locations for the pump on the tank deck.

14.9 Inert gas monitoring

14.9.1 Systems providing inert gas to cargo spaces are to be provided with a loss of pressurization and an overpressure alarm (minimum setting 3,5 kPa underpressure and 7 kPa overpressure, *see also* Pt 5, Ch 13,9) for the relevant cargo spaces. The alarms are to be both audible and visual and are to be provided on the wheelhouse.

14.10 Cargo control rooms

14.10.1 Where a cargo control room is provided for the monitoring and control of cargo operations, the arrangements are to comply with 14.10.2 to 14.10.4.

14.10.2 The applicable alarms and indications required by Sections 13 to 15 (including those for cargo tank level, temperature and pressure) are, additionally, to be provided in the cargo control room.

14.10.3 Where means to control cargo valves remotely are provided, these are to permit control from the cargo control room.

14.10.4 Cargo pump room ventilation outlets are to be situated at least 6 m from accommodation entrances.

14.11 Cargo pump room gas detection

14.11.1 Pump rooms below the upper deck are to be provided with a system of gas detection that satisfies the requirements of 13.13.4 to 13.13.12, as applicable.

14.11.2 The gas detection system is to automatically isolate electrical equipment that does not satisfy the constructional requirements of 13.13.4 and provide audible and visual alarms in the pump room and in the wheelhouse to indicate detection of gas when a gas concentration of 10 per cent of the *lower explosive limit* (LEL) of the gas resulting from leakage from the intended cargoes is detected. The arrangements are to prevent automatically isolated electrical equipment being energized until the atmosphere within the space is made safe.

14.11.3 Gas detection heads are to be located at the entrances to the cargo pump rooms and in appropriate lower positions in the space.

14.12 Cargo tank heating

14.12.1 Where thermal oil or hot water cargo tank heating arrangements are provided that includes equipment located outside of dangerous zones and spaces, arrangements are to be provided to activate an audible and visual alarm in the event of loss of heating system overpressure required to prevent cargo fluids entering heating system piping as a result of leaks in the heating system coils or other components located in the tank. Alarms are to be activated at an appropriate pressure taking into account, as necessary, the heating system operating pressures and design cargo static head.

14.13 Tank deck sprinkler systems

14.13.1 Sprinkler systems installed on tank deck are to be provided with means of control in the wheelhouse and locally.

■ *Section 15* Additional requirements for tankers intended for the carriage in bulk of other hazardous liquids

15.1 General

15.1.1 For cargoes possessing flammable characteristics similar to those of oil products, the requirements are to be based on the closed cup test flash point and vapour pressure at ambient temperature.

15.1.2 For cargoes having a flash point of 60°C and below (closed cup test), 14.1 to 14.6 are to be complied with where applicable. This requirement is based on the assumption that there are no additional hazards due to chemical reaction.

15.1.3 For cargoes which, due to chemical instability or chemical reaction may generate flammable gases or vapours, the electrical installation is to be in accordance with 15.1.2.

15.1.4 Where the cargo is liable to damage materials normally used in the construction of electrical apparatus, special consideration is to be given to the materials selected for conductors, insulation and metal parts and/or the protection thereof.

■ *Section 16* Special requirements for lightning conductors

16.1 General

16.1.1 Lightning conductors are to be fitted to each mast of all wood, composite, and steel ships having wooden masts or topmasts. They need not be fitted to steel ships having steel masts. Where lightning conductors are fitted they are to comply with Pt 6, Ch 2,14 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

■ *Section 17* Additional requirements for passenger ships

17.1 General

17.1.1 Passenger ships are to comply with the applicable additional requirements of this Section.

17.2 Main fire zones and damage stability

17.2.1 Where the ship contains main fire zones, emergency services and their emergency power supplies that are required to be capable of being operated under fire conditions or in the event of damage are to be so arranged that a fire in a main fire zone does not affect the operation of the emergency services in any other main fire zone.

17.2.2 Where the ship contains flooding zones for damage stability, electrical equipment (for example cables and connections, switchboards, section and distribution boards and protective devices) required to provide essential services required for the propulsion and safety of the ship and for emergency services are to be located above the damage stability level as far as is practicable.

17.3 Lighting

17.3.1 Lighting is to be provided by suitable electrical equipment only.

17.3.2 For the following spaces and locations, both main and emergency lighting is to be provided:
(a) at all stowage and designated preparation positions for life-saving appliances;
(b) at all muster stations and, where applicable, embarkation stations and oversides;
(c) escape route alleyways, stairways and exits;
(d) accommodation areas, cabins and personnel lift cars;
(e) in other areas intended for use by persons with reduced mobility;
(f) in the machinery spaces and main generating stations, including their control positions and their exits;
(g) in the wheelhouse;

(h) at all stowage positions for fireman's outfits;
See also 2.7.4.

17.3.3 Where required, additional emergency lighting indicating escape routes and emergency exits (e.g. low location lighting) is to be provided with an emergency power supply and is to be in accordance with the relevant requirements of the appropriate National, International or Local Authorities.

17.4 Emergency services

17.4.1 The following emergency services, where required by National, International or Local Authorities, are to be provided with emergency power supplies capable of supplying the services for 30 minutes:

- emergency lighting;
- signal lights;
- searchlights;
- fire and general alarms;
- public address systems;
- passenger and crew warning systems;
- fire detection and alarm systems;
- fire-extinguishing systems and fire-extinguishing media release alarms;
- automatic sprinkler systems;
- control and power systems to power-operated watertight doors and fire doors and their status indication;
- personnel lifts and lifting equipment for persons with reduce mobility provided for evacuation purposes;
- emergency bilge pump and equipment necessary for the operation of remote controlled bilge valves; and
- davits and hoisting gear for gangways intended for emergency use and rescue boats, where installed.

17.4.2 Emergency arrangements to bring the lift cars to deck level for the escape of persons are to be provided supplied from an emergency power supply. The passenger lift cars may be brought to deck level sequentially in an emergency.

17.5 Passenger and crew warning system

17.5.1 An internal alarm system is to be provided that permits persons on board to alert responsible ship personnel and is to be in accordance with 17.5.2 to 17.5.5.

17.5.2 The system is to be provided with means of activation at the following places:

- in each cabin;
- in corridors, lifts and stairwells with the distance to the nearest trigger not exceeding 10 m and with at least one trigger for each watertight compartment;
- in lounges, dining rooms and similar recreation rooms;
- in toilets, intended for use by persons with reduced mobility;
- in engine rooms, galleys and similar rooms where there is a fire risk; and
- in the cold-storage rooms and other store rooms with deck surface area greater than 4 m^2.

Additional means of activation may be provided at other locations considered appropriate.

17.5.3 The means of alarm activation are to be protected against unintentional use and are to be installed at a height above the deck of 0,85 m to 1,10 m.

17.5.4 Upon activation, an alarm is to be given in designated areas for the responsible ship personnel.

17.5.5 The system is to be arranged to allow alarms to be reset, accepted or otherwise handled only by responsible ship personnel.

17.6 General emergency alarm system

17.6.1 Required electrically operated bell or klaxon or other equivalent warning systems for sounding the general emergency alarm signal are to comply with the relevant requirements of the appropriate National, International or Local Authorities and with the requirements of this sub-Section.

17.6.2 The system is to be capable of sounding a clearly distinguishable general emergency alarm in:
(a) all rooms accessible to passengers; and
(b) all spaces occupied by shipboard personnel (including crew recreation rooms, cold-storage rooms and other store rooms).

17.6.3 Means are to be provided to allow the system to be capable of sounding the alarm required by 17.6.2(b) independently of the alarm to the passenger spaces required by 17.6.2(a).

17.6.4 Means are to be provided to permit the alarm to be activated from the wheelhouse and from a location that is permanently attended by ship personnel.

17.6.5 The means of alarm activation are to be protected against unintentional use.

17.7 Public address system

17.7.1 Required public address systems are to comply with the relevant requirements of the appropriate National, International or Local Authorities and with the requirements of this sub-Section.

17.7.2 The public address system is to be capable of broadcasting messages from the wheelhouse to:

- all passenger areas;
- control stations where there is no other direct communication means from the wheelhouse; and
- in the access and evacuation areas for passengers.

Loudspeakers may be omitted in passenger areas where it can be demonstrated that effective direct communication between the wheelhouse and the passenger area is possible due to proximity and the lack of barriers.

17.7.3 The system is to be designed in such a way as to ensure that the information transmitted can be clearly distinguished from background noise.

17.8 Watertight doors

17.8.1 The electrical power required for power-operated sliding watertight doors is to be separate from any other power circuit. Watertight doors are to be capable of being supplied with main and emergency electrical power.

17.8.2 A single failure in the power operating or control system of power-operated sliding watertight doors is not to result in a closed door opening or prevent the hand operation of any door.

17.8.3 Availability of the power supply is to be continuously monitored at a point in the electrical circuit adjacent to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm in the wheelhouse.

17.8.4 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of the door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

17.8.5 The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water with ratings as defined in *IEC 60529: Degrees of protection provided by enclosures (IP Code)* or an acceptable and relevant National Standard, as follows:

(a) Electrical motors, associated circuits and control components, protected to IPX7 standard.
(b) Door position indicators and associated circuit components protected to IPX8 standard, where the water pressure testing of the enclosures is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.
(c) Door movement warning signals, protected to IPX6 standard.

17.8.6 Watertight door electrical controls including their electric cables are to be kept as close as is practicable to the bulkhead in which the doors are fitted and so arranged that the likelihood of them being involved in any damage which the ship may sustain is minimized.

17.8.7 An audible alarm, distinct from any other alarm in the area, is to sound automatically whenever the door is closed by power. When a door is closed remotely, the audible alarm is to sound for at least five seconds but no more than ten seconds before the door begins to move and is to continue sounding until the door is completely closed. The audible alarm is to be supplemented by an intermittent visual signal at the door in passenger areas and areas where the noise level exceeds 85 dB(A).

17.8.8 Power operated watertight doors are to be provided with an additional hand-operated mechanism capable of operating independently of the power operation. It is to be possible to open and close the door by hand at the door itself from either side. Direction of rotation or other movement is to be clearly indicated at door operating positions.

17.8.9 Power operated watertight doors are to be capable of being closed in not more than 60 s with the ship in the upright position. The closing time of watertight doors is not to be less than 30 s. The time necessary for the complete closure of the door, when operating by hand gear, is to not exceed 90 s with the ship in the upright position.

17.8.10 Indicators are to be provided at watertight door remote control positions to indicate when a door is fully closed or open.

17.8.11 The arrangements are to be such that it is not possible to remotely open any watertight door.

■ *Section 18* **Trials**

18.1 General

18.1.1 Before a new installation, or any alteration or addition to an existing installation, is put into service the trials in 18.2 to 18.5 are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works.

18.2 Insulation resistance

18.2.1 Insulation resistance is to be measured using a self-contained instrument such as a direct reading ohm-meter of the generator type applying a voltage of at least 500 V. Where a circuit incorporates capacitors of more than 2 μF total capacitance, a constant-voltage type instrument is to be used to ensure accurate test readings.

18.2.2 **Power and lighting circuits**. The insulation resistance between all insulated poles and earth and where practicable, between poles, is to be at least 1 MΩ. The installation may be subdivided and appliances may be disconnected if initial tests produce results less than this figure.

18.2.3 **Low voltage circuits**. Circuits operating at less than 50 V are to have an insulation resistance of at least 0,33 MΩ.

18.2.4 **Switchboards, section boards and distribution boards**. The insulation resistance is to be at least 1 MΩ when measured between each busbar and earth and between busbars. This test may be made with all circuit-breakers and switches open, all fuse links for pilot lamps, earth fault-indicating lamps, voltmeters, etc., removed and voltage coils temporarily disconnected, where otherwise damage may result.

18.2.5 **Generators and motors**. The insulation resistance of generators and motors, in normal working condition and with all parts in place, is to be measured and recorded. The test should be carried out with the machine hot, if possible. The insulation resistance of generator and motor cables, field windings and control gear is to be at least 1 MΩ.

18.3 Earth continuity

18.3.1 Tests are to be made to verify that all earth continuity conductors and bonding straps are effective and that the bonding and earthing of metallic conduit and/or sheathing of cables is effective.

18.4 Performance

18.4.1 It is to be demonstrated that the Rules have been complied with in respect of 18.4.2 to 18.4.7.

18.4.2 Satisfactory commutation and performance of each generator throughout a run at full rated load.

18.4.3 Temperatures of joints, connections, circuit-breakers and fuses.

18.4.4 The operation of engine governors, synchronizing devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices.

18.4.5 Voltage regulation of every generator when full rated load is suddenly thrown off.

18.4.6 For alternating current and direct current generators, satisfactory parallel operation and kW load sharing of all generators capable of being operated in parallel at all loads up to normal sea or harbour working load. For alternating current generators, satisfactory parallel operation and kVA load sharing of all generators capable of being operated in parallel at all loads up to normal sea or harbour working load.

18.4.7 All essential motors and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory.

18.5 Voltage drop

18.5.1 Voltage drop is to be measured, where necessary, to verify that this is not excessive, *see* 2.20.

■ *Section 1* General

1.1 General

1.1.1 It is the responsibility of the Government of the flag state to give effect to the fire safety measures applicable to the particular ship type. However, Lloyd's Register (hereinafter referred to as 'LR') will undertake to do this in cases where:

(a) Contracting Governments have authorized LR to apply the requirements specified by that Government and issue the appropriate certification on their behalf; or

(b) the Government of the flag state has no relevant National requirements.

1.1.2 When implementing the provisions of 1.1.1(b), LR will apply as appropriate either:

- the fire safety measures required by EC Directive (2006/87/EC), DIRECTIVE of the EUROPEAN PARLIAMENT and of the COUNCIL of 12 December 2006 laying down technical requirements for Inland Waterway vessels; or
- the fire safety measures required by European Agreement concerning the international carriage of dangerous goods by Inland Waterways (ADN).

However, due consideration will be given to arrangements deemed to provide an equivalent level of fire safety, taking due cognisance of the circumstances of the intended service of the vessel.

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